AD-757 398

# ENTRANCE CHANNEL CURRENTS NAVAL OPERATING BASE MIDWAY ISLANDS. MODEL INVESTIGATION

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

February 1948

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DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

MISSISSIPPI RIVER COMMISSION

# ENTRANCE CHANNEL CURRENTS
# NAVAL OPERATING BASE
# MIDWAY ISLANDS

## MODEL INVESTIGATION



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TECHNICAL MEMORANDUM NO. 2-251



WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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FEBRUARY 1948

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# ENTRANCE CHANNEL CURRENTS

## NAVAL OPERATING BASE, MIDWAY ISLANDS

## Model Investigation

### SYNOPSIS

Midway Islands in mid-Pacific are the site of an important naval base. Heavy westerly seas create difficult navigating conditions in the channel passing seaward between the two islands on which the base is located. Means for alleviating these conditions with breakwaters and channel dredging were investigated on a fixed-bed model to scales of 1:500 horizontally and 1:100 vertically. The investigation was made by the Waterways Experiment Station at the instance of the Bureau of Yards and Docks, Department of the Navy.

It was found from model tests that:

a. Only those plans which provide for construction of barrier works surrounding the central lagoon would appreciably improve entrance channel conditions. These works would effectively prevent wave action from critical directions from elevating the protected lagoon waters above the level of the surrounding ocean. Other schemes of improvement works, beyond providing additional fairway and some improvement of current sets at the mouth of the entrance channel, would be of little value.

b. Breakwaters aligned parallel to the west side of the entrance channel, and extending seaward to the 40-ft depth contour, would provide fair protection from westerly storm waves. However, they would aggravate channel currents thus being objectionable unless used in combination with barrier works installed between ocean and lagoon. Additional seaward extension of the breakwater would be required to provide adequate protection from waves from the western quadrant.

c. Closure of the depression in the reef in the northwest quarter of the atoll would considerably reduce currents in the entrance channel with wave action from the west. However, with northeasterly waves, the closure of the depression would result in a general rise in the lagoon and increased currents in the entrance channel.

# PART I: INTRODUCTION

## The Prototype

1. Midway Islands, located about 1300 statute miles northwest of Honolulu, Hawaii, at longitude 177° 23' W and latitude 28° 13' N (plate 1), are geologically an atoll which is roughly kidney shaped in plan. The shape in section is that of a partially submerged dish resting upon a conical pedestal. The deep central lagoon is contained within a closely-formed coral reef ranging in height from about two feet below to about five feet above mllw. The reef is depressed in the northwest quarter, leaving a wide, shallow opening into the lagoon in that section. Sand Island (land area, about 850 acres) and Eastern Island (about 350 acres) are near the deeper, southern section of the central lagoon. Both of these small islands provide excellent locations for airfields and various other shore installations. The naturally protected deep-water lagoon adjacent to the islands affords safe anchorage for ships, and a natural opening in the south reef provides a central location between the islands for a dredged entrance channel (figure 1) leading from the ocean into the deep-water section of the lagoon. The dredge shown in the left foreground of figure 1 is located near the channel mouth. The disposition of the land and water areas of the atoll make it an ideal location for a naval base.

2. The Midway Island Operating Base, situated upon Sand and Eastern Islands, is by virtue of its location an important link in the chain of naval bases in the North Pacific Ocean. Installations at the base include docking and anchorage facilities for seaplanes, submarines,


Fig. 1. Entrance channel and submarine basin, Naval Operating Base, Midway Islands

cruisers, and other smaller type naval ships, as well as landing fields for land- and carrier-based planes. Navigation facilities consist of a dredged channel leading from the ocean into a mooring area in the central lagoon, and interconnecting channels leading into a submarine basin at Sand Island and to wharves on Eastern Island. The entrance channel, aligned north and south with a maximum width of 800 ft at the mouth and a project width of 400 ft, is dredged from the -35-ft mllw contour in the Pacific Ocean to the lagoon mooring area. A flared-mouth channel aligned in an east-west direction, and dredged to -30 ft mllw, leads from the entrance channel into the submarine basin. The channel from the southern part of the lagoon mooring area to the wharves on Eastern Island is dredged to -20 ft mllw, and is 150 ft wide.

## The Problem

3. Practical means are required for abatement of difficult and hazardous navigation conditions in, and at the mouth of, the entrance channel leading from the ocean into the mooring area in the central lagoon. These adverse navigation conditions result from the combined forces of winds, waves, and currents, and the peculiar physical shape of the atoll. Their alleviation requires a system of improvement works to reduce channel currents and wave action at the channel mouth. Reduction of currents in the entrance channel, however, is of primary concern. Other phases of the problem are improvement of navigation difficulties in the channel leading into the submarine basin, and reduction of pollution of submarine basin waters by the discharge from moored ships.

4. Tidal currents in the entrance channel are small and may be

disregarded, inasmuch as the tidal range at Midway is only about two feet.

5. Approximately three-fourths of the atoll perimeter is rimmed by a tightly formed coral reef, which ranges in relief from slightly below to four or five feet above mllw. The northwest quarter of the atoll reef is depressed, leaving an opening roughly twenty thousand feet wide with an average water depth of about fourteen feet. Waves generated by local or distant storms which attack the atoll from west to northwest directions discharge large quantities of water into the lagoon when they break over the reef and in the shallow depths of the 20,000-ft opening. When waves break in the shallow-water opening in the reef some of the energy of the forwardly-directed part of the jet is used to sustain a water-surface elevation in the lagoon above the level of the ocean. The difference between the level of the lagoon and the ocean obtains because the water discharged into the lagoon from the breaking waves cannot return to the ocean through available openings in the atoll rim until a balance is reached between the potential energy of the elevated lagoon waters and the kinetic energy remaining in the breaking waves. Thus the adverse channel currents are attributed to the difference between the water-surface elevation of the lagoon and that of the surrounding ocean. A differential of as much as 1.2 ft has been observed which caused currents of about eight feet per second near the channel mouth; this observation was made during a period of calm local weather when high seas resulting from a distant storm were running from about the northwest direction. Waves observed were approximately twenty feet high with a period of about fifteen seconds.

6. Although waves breaking on the reef from the east to the

northeast directions cast large quantities of water into the lagoon (the amount depending on tide stage and wave dimensions), they seldom cause undesirable currents in the channel because severe storms from these directions rarely occur. The large northwest opening in the reef allows outflow of most of the overtopping waters thus obviating any great difference in water-surface elevation between lagoon and ocean.

7. Midway Islands are situated in a part of the Pacific Ocean where the prevailing winds are the northeast trades in the summer season and the westerlies in the winter season. Most of the severe storms occur in the winter season and westerly storms are most prevalent. Velocities of the northeast trade winds are usually moderate and waves of large dimensions are not generated; also, since the channel mouth is alee of northeast winds, storms from this quarter seldom cause intolerable navigation difficulties. Severe storm winds from the western semicircle are most prevalent and the disposition of the topographical and hydrographical features of the atoll is such that storms from this direction create the most hazardous conditions of currents, waves, and wind at the channel mouth. Meteorological data recorded during the years 1917-1929 and 1941-1944 show that of 75 storms with wind velocities in excess of 30 knots, 54 were from the western semicircle, 2 from the north, 11 from the northeast, and 8 from east to south. The size and shape of Midway atoll are such that storms of cyclonic magnitude do not affect appreciably the ocean level near the island. However, it is probable that wind affects the relative water-surface elevations within the lagoon, the extent and location of such effects being a function of wind velocity and direction.

8. Near the channel mouth refraction causes the alignment of the fronts of west waves to change from north-south to northwest-southeast. This condition further aggravates navigation difficulties because ships navigating the mouth of the narrow channel encounter currents, waves, and wind athwart their beams. Ships with lengths of as much as 600 ft must necessarily approach the 400-ft channel at reduced speed and with a corresponding reduction in steerage. At times conditions are so severe that, due to risk of beaching, ships are forced to remain at sea. Storm winds which sweep the Pacific Ocean area in which Midway lies have maximum fetch in every direction which results in the generation of waves of considerable size. Waves approaching the atoll from the western semicircle have been observed to be as much as 20 to 40 ft in height as they broke on the west reef and, occasionally, about twenty feet in height near the channel mouth. As mentioned previously, storm waves from the western semicircle were considered of major importance relative to the channel current problem because of their size, frequency, and hydraulic effect on the atoll waters.

9. In addition to navigation difficulties in the entrance channel, cross currents in the fairway between the entrance channel and the submarine basin impede movement of tenders into and out of the submarine basin. Frequently these currents prevent moving a ship directly from the channel into the basin, requiring it to enter the lagoon mooring area, turn, and enter the basin from that direction.

10. Besides navigation problems at Midway, a pollution problem exists. The submarine basin harbors a large number of ships, and with the ships' crews quartered aboard, large quantities of raw sewage are

discharged into the basin. The location and cross-sectional area of the submarine basin entrance are such that circulation of unpolluted sea water through the basin is negligible during the normal ebb and flood of the tide.

## The Model Study

11. In a letter dated 30 November 1944, to the Chief of Engineers, subject, "Model Study of Midway Islands", the Chief of the Bureau of Yards and Docks, Department of the Navy, requested that a hydraulic model study of the problem of reducing to a minimum the hazardous navigation conditions at the mouth of the entrance channel, Midway Islands, be conducted by the Waterways Experiment Station. The Chief of Engineers authorized the model study by first indorsement, dated 2 December 1944. The study was conducted during the period June 1945 to August 1946.

12. An investigation of navigation conditions in the channel had been made before the model study was proposed. However, this investigation was primarily to provide navigators with information on sailing conditions in the channel during storms. These data plus observations of qualified observers furnished valuable information for use during the verification phase of the model study.

13. To obtain basic data from which the problem could be analyzed, and upon which verification and operation of the model could be predicated, a survey was conducted during the period 10 January to 30 April 1944. The data obtained included the magnitude and direction of entrance channel currents, storm-wave characteristics at various locations around the barrier reef, records from two automatic tide gages, and meteorological

data. It was found impossible with the equipment available to obtain adequate data during local storms. However, a severe distant storm occurred during the period 25-28 February 1945 which caused extremely hazardous conditions in the problem area, and since calm local weather conditions prevailed, it was possible to secure sufficient data for an understanding of the problem. The prototype data obtained during this period were used for model adjustment and verification.

14. During the course of the study close liaison was maintained between the agencies concerned by means of progress reports submitted at frequent intervals and conferences held both at the Experiment Station and in the Bureau of Yards and Docks. During the adjustment and verification phase of the model study Howard S. Leak, Carpenter, CEC, USNR, spent several weeks at the Experiment Station, where his advice and assistance were of material value.

15. The model study was accomplished in the Hydraulics Division of the Waterways Experiment Station. Engineers actively connected with the investigation were Messrs. F. R. Brown, R. Y. Hudson, and R. A. Jackson.

## Use of Terms

16. All quantities, both model and prototype, are expressed in this report in terms of prototype equivalents, except where otherwise stated. Various terms used throughout the report are defined below:

a. Depth, elevation. All depths and elevations specified herein are referred to mllw (mean lower low water) at Midway Islands.

b. Wave length. Wave length is the horizontal distance in

feet from crest to crest of two successive waves.

c. Wave period. Wave period is the time in seconds between the passage of two successive wave crests by any given point; that is, the time in which a wave travels one wave length.

d. Wave height. Wave height (twice the wave amplitude) is the distance in feet from trough to crest of a wave.

e. Verification. The principle of verification is based upon the proposition that a model adjusted to reproduce conditions which have occurred in the prototype can be relied upon to reproduce conditions which will occur in the prototype.

f. Base test. A base test denotes one of several tests conducted at the outset of an investigation with existing prototype elements installed in the model. These tests are performed to establish a basic condition with which to compare the results of tests conducted with proposed improvement plans installed in the model. The prototype elements used to represent base test conditions are selected from those which existed in the prototype prior to the beginning of the model study.

g. Spending beach. A spending beach is a gently sloping beach upon which waves break, expending their energy in turbulence.

## PART II: THE MODEL

### Design Considerations

17. The theoretical principles involved in the design of hydraulic models for correct reproduction of prototype phenomena are explained in modern technical literature and in reports* on model investigations published by the Experiment Station. Therefore, these principles are discussed only briefly in this report. This investigation is concerned with fluid motion phenomena such as water-wave propagation and flow with a free surface. For these conditions gravity is the predominating force component. Ordinarily, an undistorted-scale model would have been selected, but, because the area to be reproduced was extremely large and the prevailing water depths small, a distorted-scale model was required to minimize the forces of boundary friction and surface tension. Other factors which imposed the use of a model with vertical scale larger than horizontal scale were: (a) the very flat hydraulic gradients to be measured, and (b) the smallness of wave heights and velocities to be reproduced. Accordingly, a horizontal scale of 1:500 and a vertical scale of 1:100 were selected for the Midway Islands study.

18. Although the use of a distorted model results in departure from strict dynamic similarity between model and prototype, experience has shown that models of this type provide reliable information when studying phenomena such as fluid flow with a free surface where average

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* Waterways Experiment Station Technical Memorandum No. 2-237, "Model Study of Wave and Surge Action, Naval Operating Base, Terminal Island, San Pedro, California".

velocities are considered instead of precise velocity distribution. Results obtained from distorted models used for studying ocean water waves are not quantitative with respect to wave heights and patterns. However, the slight dissimilarity was not critical in this instance because wave action as such was not the major problem and the prototype currents in the entrance channel, which resulted indirectly from wave action, were verified satisfactorily on the model before testing of proposed plans was begun.

19. For models of this type the various scale ratios are based on Froude's law where velocity and time scales are functions of the vertical and horizontal scales; however, matters are not so simple when a distorted model is used to study wave action. In water where depth is great compared with wave length (depth greater than one-half wave length), waves are of the deep-water type and their velocity is a function of wave length (horizontal scale) only. In water where depth is small compared with wave length (depth less than about one-twentieth of wave length), wave velocity is a function of water depth (vertical scale) only. Between these two conditions wave velocity is a function of both wave length and water depth. The velocity and time scale derived by Froude's model law and those derived from known formulae for the velocity of waves of various lengths in various depths of water do not agree when a distorted model is used.

20. Wave velocity for both model and prototype can be determined with reasonable accuracy by means of the equation:

$$V^2 = \frac{gL}{2\pi} \tanh \frac{2\pi d}{L} \qquad (1)$$

where V is wave velocity, g is acceleration of gravity, L is wave length, d is water depth, and tanh is the hyperbolic tangent. This equation is valid so long as wave height is small compared with either water depth or wave length.

21. From equation (1) the velocity and time scale ratios may be expressed by the following relations:

$$\frac{V_m}{V_p} = \left(\frac{L_m}{L_p}\frac{\theta_m}{\theta_p}\right)^{1/2} \quad \text{and} \qquad (2)$$

$$\frac{T_m}{T_p} = \left(\frac{L_m}{L_p}\frac{\theta_p}{\theta_m}\right)^{1/2} \qquad (3)$$

where the subscripts m and p refer respectively to model and prototype terms, and $\theta$ denotes $\tanh \frac{2\pi d}{L}$ with the proper subscripts.

22. The variables in these transference equations show that, when a distorted scale model is used, the velocity and time scale ratios will change as wave length ani water depth changes. With an undistorted model the term $\theta$ in equations (2) and (3) is unity and the velocity and time scales are constant for a given linear scale, regardless of changes in wave length and depth. Therefore, when $\theta$ is unity these ratios agree with those derived by Froude's law.

23. After the test wave characteristics have been selected, it is necessary to determine velocity and time scales for this particular wave in a specific depth of water. For example, the test wave selected for this study was a 15-sec wave in 120 ft of water. By using equation (1) and the definition of velocity ($V = \frac{L}{T}$), the wave length can be computed

when the period and water depth are known. Since water depth in the model at the wave generator should correspond to water depth in the prototype where these wave characteristics were observed, time and velocity scales were determined by water depth at the wave generator. The time and velocity scales which correspond to a 15-sec wave in 120 ft of water are, model to prototype, 1:26 and 1:19, respectively. These ratios were used to determine the dimensions of model waves to correspond with the dimensions of waves in the prototype selected for reproduction on the model.

24. The varying time and velocity scales discussed above are applicable only to wave action, and are not applicable to time and velocity scales pertaining to channel flow. These last-mentioned ratios are in accordance with Froude's model law applied to distorted models. These are: time 1:50, velocity 1:10, area (horizontal) 1:250,000, area (vertical) 1:50,000, and volume 1:25,000,000.

## Description

25. The model was a fixed-bed type constructed of concrete to a linear scale of 1:500 horizontally and 1:100 vertically (figures 2 and 3). Reproduced were the entire Midway atoll and the surrounding ocean area to the 120-ft depth contour. Plate 1 shows the model layout.

26. To reproduce prototype phenomena it was necessary to elevate the water surface of the lagoon above that of the surrounding ocean. Since the total model basin area was not large enough to allow raising the water-surface elevation in the lagoon without a measurable lowering of water surface in the surrounding model ocean area, it was necessary

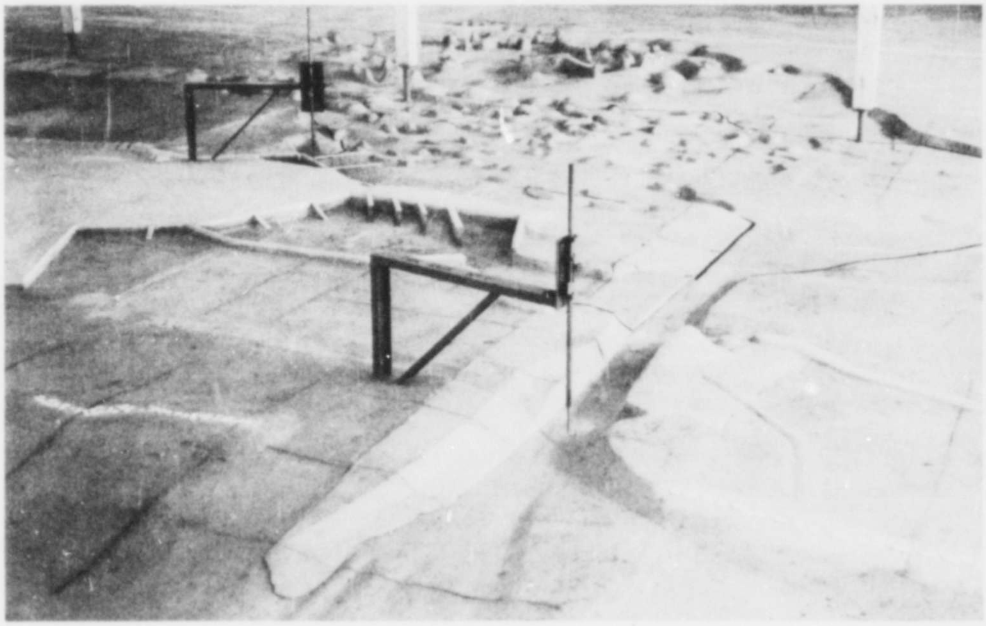


Fig. 2. Entrance channel

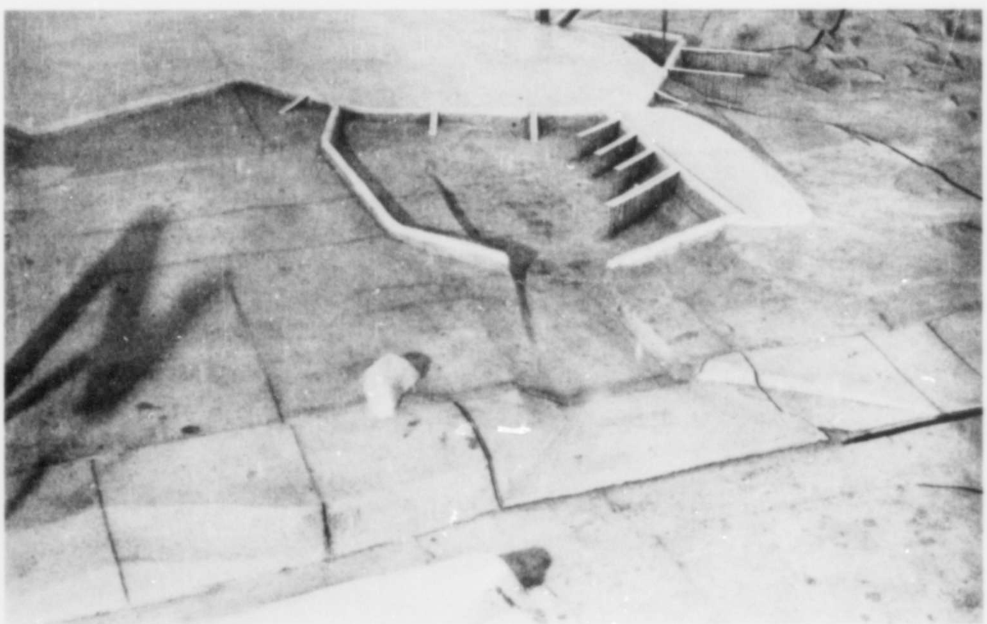


Fig. 3. Submarine basin

to provide means for maintaining a constant water-surface elevation at critical points in the model ocean area. For this purpose a circulating system was installed in the model, consisting of four interconnected headers located in the southwest, west, northwest, and northeast portions of the model with valves so located that water could be introduced at each or at all of these sections of the model. The headers were equipped with adjustable ports (figure 4) for controlling the quantity of water discharged from each port. A motor-driven, centrifugal-type pump was placed in the line between the sump and the headers and the quantity of water circulated was measured by an orifice in the line and controlled by a hand-operated gate valve. To provide outflow for the water introduced by the pump, four hand-operated adjustable overflow weirs were installed in the model. Gravity lines connected the weir pits with the sump. The locations of these weirs are shown on plate 1. Guide vanes

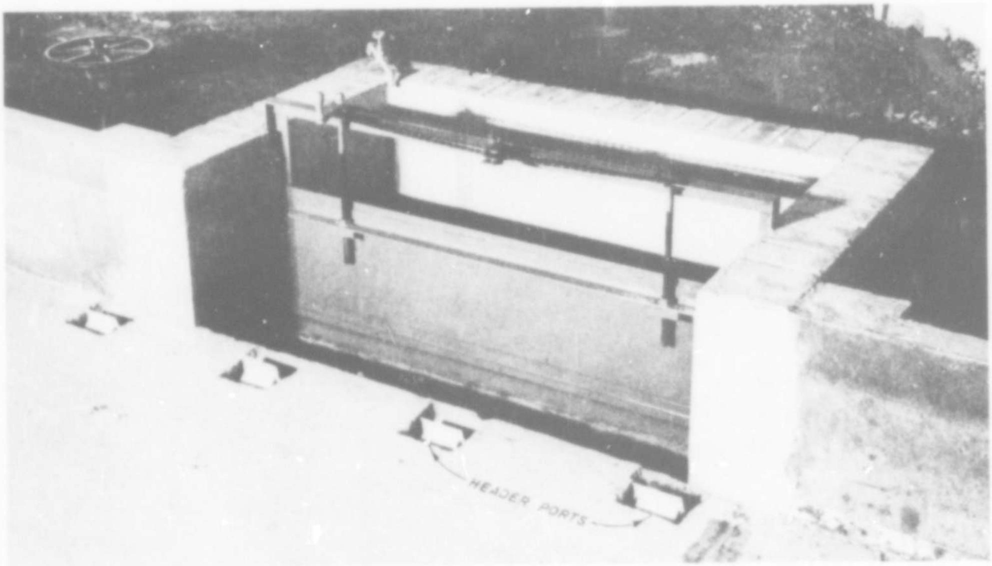



Fig. 4. Overflow weir

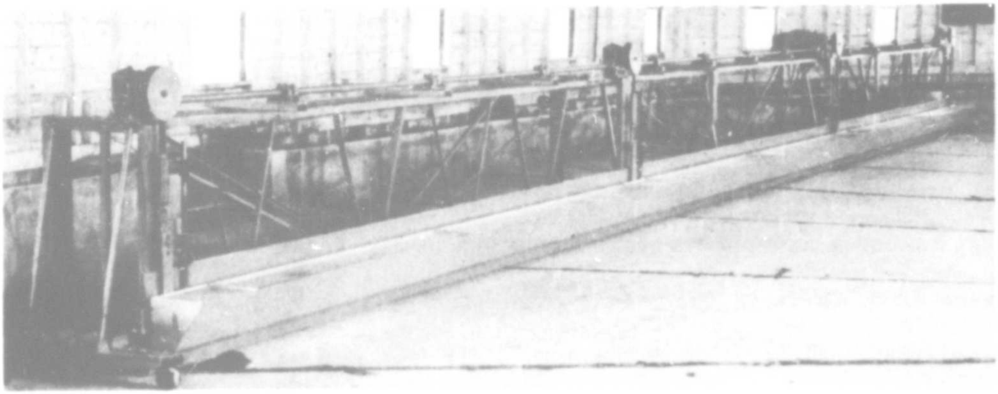


Fig. 5. Wave machine, 60-ft length

placed outside the problem area also were employed to obtain proper distribution of the circulating water.

27. Movable, plunger-type wave machines (figure 5) reproduced prototype waves in the model by displacement of water through vertical movement of the plunger. Waves of the desired characteristics were generated by using different combinations of plunger stroke, speed, and submergence. The wave machines were mounted on casters to permit positioning on the model for generating waves from desired directions (west and northeast).

28. Wave heights were measured with a gage (figure 6) consisting of a resistance staff installed in a direct-current circuit in which the resistors

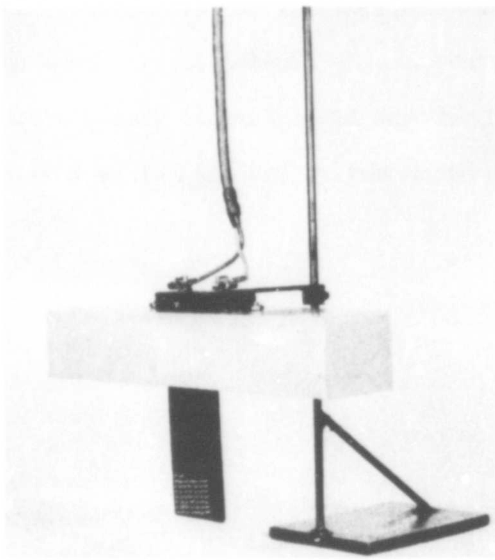


Fig. 6. Wave-height measuring device

of the electrical circuits were so designed that currents through the circuits varied directly with submergence of the staff in water. The external contacts on each gage were exposed along the face of the staff in 0.004-ft vertical increments (model). Therefore, the gages were capable of measuring vertical movements of the water surface to an accuracy of 0.004 ft in the model, corresponding to 0.4 ft in the prototype. The electrical leads from the gage staff were connected to a series of modified D'Arsonval galvanometers installed in a recording oscillograph. The deflections of each galvanometer, resulting from electrical current intensity changes in the gage staff circuit, were transmitted by a beam of light to a strip of moving, sensitized, photographic recording paper. This record or oscillogram was a two-dimensional graphic plot of model waves from which wave heights were measured.

29. Current velocities ranging from 5 to 20 ft per sec were measured with midget current meters. Lesser current velocities were measured, where depths permitted, with submerged pole-type floats. In depths of less than 10 ft surface floats were used. The accuracy of the midget current meters was insured by frequent calibration.

## PART III: THE TESTING PROGRAM

30. In general the testing procedure consisted of establishing the validity of the model for reproducing the cause and effects of channel current conditions, then installing and testing different proposed plans of improvement to determine their efficacy in correcting undesirable conditions in the problem area. The model was verified by reproducing prototype conditions which existed at a time when distant storm waves caused a rise in lagoon water-surface elevation above that of the surrounding ocean and a corresponding increase in entrance channel currents. Action of the prototype on 26 February 1945 was chosen for model verification.

### Verification of Model and Base Tests

31. Relatively large waves generated by a distant storm prevailed in the Midway area during the period 25-28 February 1945. These waves were of the 15-sec type (13- to 18-sec period). For a considerable time on 26 February the heights of these waves were such that the elevation of their crests above the lagoon water level, as they broke on the reef, averaged about fourty-four feet on the north reef and twenty-three feet on the west reef. Wave heights, measured from crest to trough, of the oncoming primary waves were estimated to be about twenty to twenty-five feet. The exact direction of the waves was not determined but evidence indicated that they were from about the northwest direction. Entrance channel currents were measured during the period from about 8:30 to 10:00 a.m. on 26 February. During this period the difference between

water-surface elevations at tide gages 1 and 2 averaged 1.2 ft (plate 7) and maximum currents in the channel were about eight to nine feet per second. The relation of water-surface elevations of the lagoon and ocean, and the velocities of entrance channel currents, were verified on the model by generating 15-sec waves from the west direction and observing the resulting water-surface differential and currents. It was found that a primary wave 20 ft high caused a differential of 1.2 ft and that resulting channel currents in the model, after slight modifications of channel roughness, conformed very closely to those which had been observed in the prototype. These data are shown on plate 7. Base test conditions were used for these tests, and results of this verification test were also used as the base test for all improvement plans tested with 20-ft waves from the west direction.

32. A few tests were conducted using waves from the northeast direction, but without model verification due to lack of prototype data. However, since the model had successfully reproduced prototype channel currents when the water-surface differential between lagoon and ocean was equivalent to that which had occurred in the prototype, it was thought that the model could reproduce prototype conditions caused by comparable primary waves from other directions -- despite the fact that waves used on the model to establish correct water-surface elevations were generated from the west direction, whereas prototype waves were thought to be from the northwest direction. Thus, for tests with waves from the northeast a base test was performed using 15-sec waves 20 ft in height. Results of this test were utilized to judge the relative effects of the different plans tested with waves from the northeast direction. Results of the

base test for waves from the northeast direction are shown on plate 11.

## Data Secured on the Model

### Currents

33. With each proposed improvement plan installed in the model, and with test conditions as previously described, current-pattern data were obtained as shown on plates 7-29. The currents on these plates represent the arithmetical mean of velocities measured during two test runs conducted with identical test conditions. Current directions represent the general set of subsurface currents. Comparison of results obtained from the test of a plan with the appropriate base test -- or with another plan -- indicates the relative worth of the plan for improving adverse navigation conditions caused by strong currents. Evaluation of the effects of elements of various plans should be based primarily on results obtained at stations located within the limits of the navigation channel system, with particular regard for conditions at the channel mouth. Plate 6 shows the locations of velocity observation stations.

### Water-surface elevations

34. Unfortunately, water-surface profiles of channel flow in the prototype were not available. It was possible, however, to measure water-surface elevations in the model problem area, but wave action in the channel interfered somewhat with measuring this quantity by means of a point gage and these measurements are considered approximate. Water-surface profiles were used to complement the current-pattern data so as to present a better over-all picture of conditions in the lagoon and

channels resulting from waves breaking on the atoll reef.

Wave heights

35. For each proposed improvement plan waves were generated from the west direction, and for tests of two of the plans waves were generated from the northeast direction. Wave heights were measured at the locations shown on plates 37-52. Comparison of the results of wave-height tests for each plan of improvement with the wave-height test of the appropriate base test shows the relative effectiveness of each plan in protecting the problem area from wave action. Comparisons of test results of similar or dissimilar plans provide a good method of evaluating the effects of different elements of the plans. Evaluation of the effects of elements of various plans should be based primarily on results obtained at model wave gages 7, 9, 10, and 12 which are located in the critical area of the channel mouth.

## Plans Tested

36. During the course of the investigation tests were conducted on 16 plans of improvement. Elements of these plans, as installed in the model, are shown on plates 2-5.

37. At the outset of the study several possible solutions to the Midway problems were suggested: (a) dredging a new entrance channel, aligned in an east-west direction, connecting the lagoon mooring area with the ocean via Welles Harbor; (b) removal of several thousand feet of the barrier reef along the eastern periphery of the atoll; and (c) removal of spoil banks and coral heads along both sides of the existing entrance channel. However, after careful study of the problem and the

degree of improvement desired for various elements of the problem area, it was decided to test the following four general plans of improvement works:

<u>a</u>. Plans 1, 1A, and 2, consisting of widening the entrance channel mouth together with various breakwaters on the west side of the channel extending from the south submarine basin breakwater via Swan Isle to about the -40-ft mllw contour in the Pacific Ocean. Also incorporated in this scheme was a spending beach on the east side of the channel mouth. The primary purpose of these plans was to improve navigation conditions by providing more protected maneuver area for ships entering the channel, and to improve entrance conditions into the submarine basin.

<u>b</u>. Plans 3, 3A, and 3B involving widening the entrance channel by increments of 200 ft, from 400 ft to 1000 ft. These plans were tested to study the effect of a wider channel on the water-surface differential between lagoon and ocean.

<u>c</u>. Plans 4, 4A, 4A-1, and 4B, providing for a 1000-ft-wide entrance channel with various breakwaters on the west side of the channel extending from the south submarine basin breakwater and paralleling the channel to about the -40-ft mllw ocean contour. A spending beach on the east side of the channel mouth was also included as a modification of this general scheme. Generally, this scheme was tested for comparison with scheme <u>a</u>, which was similar except for channel width.

<u>d</u>. Plans 7 and 8, comprising breakwaters which inclosed by various alignments the deep-water area of the central lagoon. The purpose of these breakwaters was to provide a barrier for protecting the lagoon from ocean wave action, thereby reducing or eliminating the water-surface differential between the two bodies of water. Modifications involving the use of various heights of portions of the south reef near the entrance channel were added to this general scheme (plans 5, 6, 7A, and 7B).

38. The following table shows the length and approximate volume for each breakwater tested, and the volume of dredged material for proposed channel improvement. Breakwater yardages were calculated using a section with a crown width of 15 ft at 7 ft and 10 ft mllw, depending on breakwater location. Seaside side slopes were 1:2 from crown to -10

ft mllw, and 1:1-1/4 from -10 ft mllw to bottom. Harbor side slopes were 1:1-1/2 from crown to -10 ft mllw, and 1:1-1/4 from -10 ft mllw to bottom. The volumes shown represent gross volume of the breakwater sections. The dredging quantities were calculated using a channel depth of 35 ft with side slopes of 1:2.

TABLE 1

Lengths and Volumes of Breakwater Plans, and Volumes of Dredging for Channel Improvement

| Plan | Elements | | |
|---|---|---|---|
| | Breakwater Structure | | Channel Dredging |
| | Length in Ft | Volume in Millions of Cu Yd | Volume in Millions of Cu Yd |
| 1 | 3080 | 0.08 | 0.67 |
| 1A | 3080 | 0.08 | 0.86 |
| 2 | 4980 | 0.23 | 0.86 |
| 3 | - | - | 0.91 |
| 3A | - | - | 1.94 |
| 3B | - | - | 2.97 |
| 4 | 1700 | 0.06 | 2.97 |
| 4A | 3800 | 0.12 | 2.97 |
| 4A-1 | 3800 | 0.12 | 3.19 |
| 4B | 5700 | 0.35 | 2.97 |
| 5 | 750 | 0.01 | - |
| 6 | 7700 | 0.74 | - |
| 7 | 40,600 | 0.89 | - |
| 7A | 48,300 | 0.97 | - |
| 7B | 49,900 | 1.13 | - |
| 8 | 24,200 | 0.67 | - |

## Special Tests

39. During the course of the investigation, tests using 15-sec waves with heights of 5, 10, 15, 20, and 30 ft were conducted to establish a relation between the height of the attacking waves and the corresponding lagoon level. These tests were conducted with waves from

the west direction and with base test conditions installed in the model. Data obtained from these tests consisted of water-surface differentials between lagoon and ocean and the resulting current velocities and patterns. By estimating the height of the waves attacking the atoll, and applying this estimated value to the curves as shown by figure 7, page 36, the approximate velocity of the channel currents can be predicted.

40. A few tests were made to study the problems of pollution in the submarine basin, but it was found that an accurate reproduction of the tidal cycle was necessary for tests of this type. Because of the considerable cost involved in the installation of tide-reproducing apparatus, these tests were discontinued.

## PART IV: RESULTS OF TESTS

41. The relative efficacy of each plan is shown for selected critical locations in the problem area in tables of percentile change of current velocities and in tables of wave heights. Expressed algebraically, percentile change is equal to $\frac{W_1 - W_2}{W_1} \times 100$, where $W_1$ is the value of a velocity or wave height at a particular location for the base test, and $W_2$ is the corresponding value for a particular plan. The localities selected for calculating percentile changes were the channel mouth near the position of tide gage 2, the mid-point of the longitudinal axis of the entrance channel, and the submarine basin channel.

42. Current-pattern data for base test and plans 1-8 are shown in tables 2 and 3, pages 38 and 39, and in tables 6 and 7 following the text. Photographs 1, 3, 5, 7, 9, 10, 11, 13, 15, and 16 and plates 9-36 also show these data. Tables 2 and 3 show the results as percentile change in current velocity, and tables 6 and 7 show both velocity and corresponding water-surface (slope) data. The photographs listed above show current patterns in the entrance channel for base tests and plans 2, 4B, 7, 7B, and 8. Current patterns are also shown for base test and plans 1-8 on plates 9-29. Plates 30-36 show velocities and water-surface profiles at selected stations for base test conditions compared with corresponding data for plans 1-8.

43. The results of wave-height tests for base test conditions and plans 1-8 are shown in tables 4 and 5, page 40, in table 8 following the text, and on plates 37-52. Tables 4 and 5 show the results as percentile changes in wave heights in selected areas; table 8 shows wave heights in

feet; and plates 37-52 show the results of wave-height tests for base test conditions compared graphically with those of the several plans.

## Plans 1, 1A, and 2

44. The elements of plans 1, 1A, and 2 (plate 2) consisted of widening the entrance channel mouth in combination with a system of breakwaters of varying lengths located on the west side of the entrance channel. The general alignment of these breakwaters was southeastward from the east end of the south submarine basin breakwater via Swan Isle to a point near the west bank of the entrance channel. Modification of this breakwater plan consisted of extending the structure southward parallel with the west bank of the channel to about the -40-ft depth contour in the Pacific Ocean. This general scheme also included a spending beach on the east side of the widened channel mouth. The spending beach was added to plan 1 to form plan 1A, and the additional breakwater (that part which extended to -40 ft mllw) was added to plan 1A to form plan 2. The purpose of these plans was the improvement of navigation conditions at the channel mouth by providing more protected maneuver area for ships moving in and out of the channel. It was not expected that these plans would be especially effective in reducing entrance channel currents; however, it was thought that they would effect some improvement of navigation conditions in the submarine basin channel.

45. Results of the plan-1 series showed little over-all improvement in navigation conditions except for some slight betterment at the entrance channel mouth. Currents at the channel mouth and in the vicinity of tide gage 2 were reduced slightly, but farther up the channel,

especially at about its mid-point, the currents were increased. The unfavorable southward set of the currents across the submarine basin channel which occurred for base test conditions was changed to southeastward which probably would improve navigation conditions in this area. The principal improvement noted with the plan-1 series installed was the reduction of currents on the west side of the channel mouth. This decrease in currents, coupled with the increased maneuver area provided by the improvement works, should improve somewhat navigation conditions in this critical navigating area.

46. The increase in channel currents obtained with the plan-1 series installed was caused by the steeper hydraulic gradient of channel flow. With base test conditions installed the great quantity of water which flowed eastward between the south shore line of Sand Island and the coral reef on the south joined the entrance channel flow between Swan Isle and the channel mouth (photograph 1 and plate 10). Installation of breakwaters on the west side of the channel diverted this flow from its natural course, forcing it to join the channel flow immediately south of tide gage 2. This diversion of flow caused a lowering of water-surface elevation from zero (base test conditions) to -0.8 ft mllw at tide gage 2. The effect of this diversion, which reduces the volume of channel flow past tide gage 2, was that zero stage moved up-channel from gage 2 to about the mid-point of the channel. Since the lagoon water-surface elevation was unchanged by the plan's installation, and since the location of zero water-surface elevation moved up-channel, the horizontal distance between these points was decreased thereby causing an increase in current velocity. Comparative water-surface profiles for

base test conditions and plans 1 and 1A are shown on plate 30. Plans 1 and 1A reduced wave heights slightly in the submarine basin and the upper reaches of the entrance channel. However, the spending beach of plan 1A was not very effective in reducing wave heights at the channel mouth.

47. Although plan 2 caused a general increase in entrance channel currents, the set of the currents at the channel mouth was changed from southeasterly to southerly (photograph 5 and plate 14). This change in current direction improved navigation conditions at the channel mouth, and this improvement is believed to outweigh the disadvantages of increased currents. Extension of the plan-1A breakwater to the -40-ft contour (plan 2) provided some slight protection for the channel mouth from westerly storm waves. These tests show that more breakwater length than provided by plan 2 is necessary to protect the channel mouth from waves from the west direction (photograph 6).

## Plans 3, 3A, and 3B

48. Plans 3, 3A, and 3B (plates 2 and 3) consisted of widening the existing 400-ft entrance channel width by 200-ft increments to 600-, 800-, and 1000-ft widths, respectively; the widening was performed on the east side of the existing channel. Project depths in the channel were 35 ft, and side slopes were 1:2. These plans were devised for the dual purpose of providing additional maneuver area and for studying the effects of a widened waterway on channel currents.

49. Test results of the plan-3 series showed that these plans would improve navigation conditions somewhat by virtue of the additional maneuver area provided, and that certain of these plans would help conditions

by changing current patterns at the channel mouth. In general, the effect of channel widening was an increase in the hydraulic efficiency of the channel, with a corresponding slight increase in currents.

50. The 600-ft channel (plan 3) increased the currents approximately 0.5 ft per sec throughout the channel length, with little change in flow patterns (plate 15). Both plans 3A and 3B increased channel currents slightly; however, these plans improved to some extent the set of the currents at the channel mouth (plates 16 and 17). The improved current pattern, together with the increased maneuver area provided by plans 3A and 3B, should ameliorate navigation conditions regardless of the slight increase in velocities caused by these plans.

51. The plan-3 series was not designed to provide wave protection at the channel mouth, and wave heights were not appreciably changed by these plans except for a negligible reduction in the lower reaches of the channel.

## Plans 4, 4A, 4A-1, and 4B

52. Elements of the plan-4 series (plates 3 and 4) consisted of widening (on the east side) the existing 400-ft channel width to 1000 ft, in combination with various lengths of breakwater aligned parallel to the west bank. The plan-4 breakwaters consisted of a structure beginning at the east end of the south submarine basin breakwater and extending southeastward and about parallel to the submarine basin channel to a point near the junction of the entrance channel and submarine basin channel. Plan 4A was the same as plan 4 except that the breakwater was extended southward and parallel to the entrance channel to a point opposite the

beginning of the channel flare on the west. The spending beach on the east side of the channel mouth was added to plan 4A to form plan 4A-1. To form plan 4B the plan-4A breakwater was extended southward and parallel to the west bank of the channel to about the -40-ft depth contour.

53. Navigation improvement in the entrance channel was about the same for this series of plans as it was for the plan-3 series. Some improvement of current patterns was effected in the submarine basin channel and at the mouth of the entrance channel (plates 18-21). The increased hydraulic efficiency of the plan-4 series of channels caused a slight increase in channel velocities. Plans 4 and 3B were identical except that plan 4 added a breakwater parallel to the south bank of the submarine basin channel. This breakwater installation caused currents across the submarine basin channel to change from a southerly to a southeast direction, which change should improve navigation conditions for ships passing in and out of the submarine basin. Compared with plan 4, plans 4A and 4A-1 did not improve navigation conditions in the entrance channel. The additional length of the plan-4A breakwater, and the spending beach of plan 4A-1, were not effective. It can be seen from plates 9 and 10 that, under existing prototype conditions, there is considerable flow into the entrance channel from the area west of the channel and southeast of Sand Island. The breakwaters of plans 4A, 4A-1, and 4B diverted this flow, which resulted in an increase of the hydraulic gradient with a corresponding increase of channel currents. The longer breakwater of plan 4B effected a more complete diversion of flow into the channel from the west, and, therefore, caused a greater increase in velocity than did plans 4A and 4A-1 (plates 19-21 and photograph 7).

54. Plans 4, 4A, and 4A-1 protected the channel mouth only slightly from wave action; breakwater lengths were insufficient to provide protection to the area, and the spending beach of plan 4A-1 appeared to be ineffective. Extension of the plan-4A breakwater to about the -40-ft depth contour in the ocean (plan 4B) provided a fair degree of protection -- about 25 per cent reduction in wave heights. However, these tests showed that if complete protection of the channel mouth from westerly waves were obtained, the breakwaters would have to be extended southerly for considerable distance.

## Plan 5

55. Plan 5 (plate 4) provided for a short connecting breakwater aligned northwest to southeast across the shallow-water area between the south shore line of Sand Island and the coral reef on the south. The magnitude and direction of channel currents were practically unchanged by this plan; currents near the mid-point of the channel length and in the submarine basin channel were increased slightly. This plan provided no protection from wave action. Test results (plate 22) showed that plan 5 would have little effect on navigation conditions in the entrance channel.

## Plan 6

56. Elements of plan 6 (plate 4) included the short breakwater of plan 5 in conjunction with raising the coral reef from the reef terminus of plan 5 to a point about 1300 ft west of the west bank of the entrance

channel. This plan was tested to determine the effects of diverting from the channel the vast quantity of water that flows between the south shore line of Sand Island and the adjacent coral reef.

57. Results of tests of plan 6 showed little betterment of navigation conditions. In general, currents were increased slightly, except in the vicinity of tide gage 2 where a slight reduction was noted. Flow patterns at the channel mouth were about the same as with existing conditions (plate 23). Flow patterns in the submarine basin entrance channel were changed from southward to southwestward, which change was not an appreciable improvement of navigation conditions in this channel. Installation of plan 6 effected very little reduction of wave heights except in the submarine basin channel where the degree of reduction compared favorably with the reduction effected by plan 2 and the plan-4 series.

## Plans 7, 7A, and 7B

58. Elements of the plan-7 series are shown on plate 5. The basic element of this series consisted of inclosing the deep-water area of the central lagoon with an impervious breakwater. Plan 7A consisted of plan 7 plus the elements of plan 6. Plan 7B consisted of all the elements of plan 7A plus a spur breakwater aligned northwest to southeast, forming an obtuse angle with the main structure, and extending southeastward to the -40-ft depth contour in the Pacific Ocean.

59. Test results of the plan-7 series show that these plans would provide excellent navigation conditions in the entrance channel (plates 24-27). Plan 7 effected an over-all reduction in current velocities of about 50 per cent and plans 7A and 7B provided about 80 per cent reduction

for waves from the west direction. With any of the plans of this series installed in the prototype the differential between lagoon and ocean would be insignificant, and currents in the entrance channel would be very small. The slow-speed currents which obtained with these plans installed in the model were caused by the relatively small quantities of water which entered the lagoon on the south side of the atoll between Sand and Eastern Islands. With respect to protection from wave action (waves from the west) at the channel mouth, plan 7B was the only plan of this series which extended far enough south to be of any benefit (photograph 12 and plate 51). Plan 7 was tested also for waves from the northeast. It was found that currents in the channel and wave heights at the channel mouth were too small to cause troublesome navigation conditions in the channel (photograph 10 and plates 25 and 49).

## Plan 8

60. Plan 8 consisted of an impervious breakwater aligned convex to the sea, connecting the west end of the north barrier reef with the northwest corner of Sand Island (plate 5). This plan was tested to determine the effects on lagoon water level of closing the gap in the coral reef on the west. Preliminary tests indicated that closure of the gap would reduce effectively the lagoon water level which obtained with wave action from the west direction, but it was thought that a plan of this type would be unsatisfactory for northeast waves. Therefore, it was decided that plan 8 should be tested with waves from both the west and northeast directions.

61. For waves from the west direction navigation conditions in the

entrance channel were about the same for plan 8 as they were for plan 7. The over-all reduction in channel currents was about 50 per cent for both plans 7 and 8 (photograph 13 and plate 28). Wave heights at the channel mouth also were reduced slightly (plate 52), probably due to elimination of the steep wave fronts caused by strong currents which prevailed before plan 8 was installed.

62. For waves from the northeast direction plan 8 caused much worse navigation conditions in the entrance channel than obtained with either base test conditions or any of the other plans tested. With base test conditions and waves from the northeast direction, the lagoon water level was only about 0.9 ft above the ocean water level. With plan 8 and waves from the northeast, the water surface of the lagoon was raised 5 ft above the surrounding ocean level (plate 36). This extreme lagoon level caused by plan 8 resulted in an over-all increase in channel currents of about 180 per cent. For base test conditions with waves from the northeast the currents in the vicinity of tide gage 2 were about six feet per second, while with plan 8 installed and using similar test conditions, currents in this locality were increased to about twenty feet per second. With base test conditions the lagoon level was about 0.3 ft greater for west waves than it was for northeast waves. This indicates that some of the inflow caused by northeast waves escapes through the wide depression in the reef on the west side of the atoll. With plan 8 installed the gap in the reef is closed, and water cast into the lagoon by northeast waves must escape principally through the entrance channel; as a result, currents in the entrance channel are increased considerably. With waves from the northeast direction wave

heights at the channel mouth were practically unchanged by plan 8.

## Special Tests

### Wave-height lagoon-level relations

63. The current velocities and water-surface elevations which obtained with the various wave heights for wave-height lagoon-level tests are shown by figure 7. Plates 53-56 show the currents which resulted from wave heights of 5, 10, 15, and 30 ft, and plate 10 shows similar data for 20-ft waves. These data are presented also in table 9 following the text.

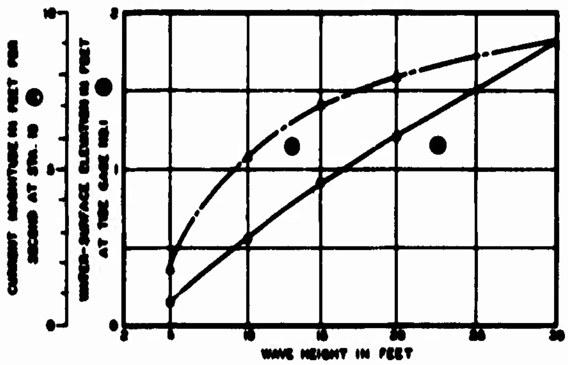



Fig. 7
Wave-height lagoon-level relations

64. These data indicate the maximum conditions which would obtain in the entrance channel for primary storm waves up to 30 ft in height. The curves of figure 7 show that the lagoon level, as measured by the water-surface elevation above mllw at tide gage 1, varies directly (for all practical purposes) with wave height -- at least for wave heights up to 30 ft -- but that the slope of the curve, entrance channel currents versus wave height, decreases as wave height increases. From these data it is estimated that the greatest current velocity in the entrance channel for the highest west waves which would occur in the prototype area would not be much larger than about ten feet per second. It is thought that the reason entrance channel currents do not continue to

increase appreciably with increased lagoon level, for wave heights above about 25-30 ft, is that after the lagoon water surface has reached an elevation of about 1.75-2.00 ft above mllw, due to waves from the west, larger quantities of the inflow discharge through the openings in the reef around the atoll perimeter. This condition would obtain only for waves from the west with no local wind, and with the relatively inefficient channel which now exists in the prototype. Higher velocities would occur, no doubt, with local wind from the west-northeast direction or with a wider and more efficient channel installed.

## Resume of Results

### Currents

65. Navigation conditions at the channel mouth were improved slightly by plans of the plan-1 group and by plan 2. These plans provided a wider channel mouth and some reduction of current velocities at the channel mouth; currents in the upper reaches of the channel, however, were not altered appreciably. The wider channels of the plan-3 series improved navigation conditions by providing more maneuver area and current directions more favorable to navigation. On the other hand, resistance to flow is decreased with these plans installed, and currents are increased accordingly. Conditions resulting from the plan-4 installation were little different from those resulting from the plan-3B installation. However, the other plans of the plan-4 series caused a considerable increase in entrance channel velocities. Current patterns and velocities with plans 5 and 6 installed in the model were very similar to those obtained for base test conditions. Excellent navigation

conditions were obtained in the entrance channel for all plans of the plan-7 series. Of all the plans tested, plan 7B provided the most reduction in current velocities in the entrance channel. The action of plan 8 was very similar to that of plan 7 for waves from the west direction. However, with waves from the northeast direction plan 8 caused conditions in the entrance channel which were much worse than those for the base test. Tables 2 and 3 show current data as percentile changes in current velocity in selected areas.

TABLE 2

Percentile Change of Currents
Waves from West

| Plan | Locale: Channel Mouth | | Tide Gage No. 2 | | Mid-Point of Channel | | Submarine Basin Channel | |
|---|---|---|---|---|---|---|---|---|
| | Red. | Incr. | Red. | Incr. | Red. | Incr. | Red. | Incr. |
| Base Test | - | - | - | - | - | - | - | - |
| 1 | 30 | - | 19 | - | - | 37 | - | 7 |
| 1A | 18 | - | 9 | - | - | 37 | - | 7 |
| 2 | 64 | - | 25 | - | - | 34 | - | 20 |
| 3 | - | 14 | - | 9 | - | 13 | - | 40 |
| 3A | - | 12 | - | 3 | - | 8 | - | 47 |
| 3B | 4 | - | 0 | 0 | - | 8 | - | 73 |
| 4 | 0 | 0 | 2 | - | - | 2 | - | 60 |
| 4A | - | 36 | - | 16 | - | 33 | - | 87 |
| 4A-1 | - | 36 | 15 | - | - | 31 | - | 93 |
| 4B | - | 50 | - | 20 | - | 34 | - | 114 |
| 5 | 4 | - | 4 | - | - | 5 | - | 16 |
| 6 | - | 16 | 10 | - | - | 13 | - | 40 |
| 7 | 48 | - | 55 | - | 56 | - | 0 | 0 |
| 7A | 58 | - | 83 | - | 81 | - | 27 | - |
| 7B | 82 | - | 87 | - | 80 | - | 73 | - |
| 8 | 48 | - | 51 | - | 48 | - | 13 | - |

TABLE 3

Percentile Change of Currents
Waves from Northeast

| Plan | Locale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Channel Mouth | | Tide Gage No. 2 | | Mid-Point of Channel | | Submarine Basin Channel | |
| | Red. | Incr. | Red. | Incr. | Red. | Incr. | Red. | Incr. |
| Base Test | - | - | - | - | - | - | - | - |
| 7 | 67 | - | 88 | - | 88 | - | 86 | - |
| 8 | - | 182 | - | 190 | - | 179 | - | 68 |

<u>Wave heights</u>

66. With waves from the west direction, plans 2, 4B, and 7B provided good protection from wave action in the channel mouth. Plans 5 and 6 provided the least protection from westerly storm waves. Of all the other plans tested, plans 4A and 4A-1 were the only plans which provided the channel mouth with appreciable protection from westerly storm waves. To protect adequately the channel mouth and the upper reaches of the channel from westerly storm waves would require a breakwater extending considerably farther seaward than that provided by any of the plans tested. Water depths in which such a structure would be located probably would prohibit construction because of costs. The benefits to navigation of a seaward breakwater are questionable unless the current problem is solved also. Plan 7B solves the current problem and also provides the best over-all protection from waves. Plans 7 and 8 were the only plans tested with waves from the northeast direction. These plans had little effect on wave heights at the channel mouth for northeast waves. However, since the channel mouth is alee of a northeast storm, wave heights in the

area with storms from this quarter are small and protection from wave action is not required. Tables 4 and 5 show percentile changes in wave heights in selected areas.

TABLE 4

Percentile Change of Wave Heights
Waves from West

| Plan | Locale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Channel Mouth | | Tide Gage No. 2 | | Mid-Point of Channel | | Submarine Basin Channel | |
| | Red. | Incr. | Red. | Incr. | Red. | Incr. | Red. | Incr. |
| Base Test | - | - | - | - | - | - | - | - |
| 1 | 4 | - | 7 | - | - | 20 | 33 | - |
| 1A | 8 | - | 19 | - | - | 20 | 33 | - |
| 2 | 34 | - | 44 | - | 20 | - | 33 | - |
| 3 | 14 | - | 29 | - | 20 | - | 17 | - |
| 3A | 21 | - | 34 | - | 20 | - | 17 | - |
| 3B | 14 | - | 34 | - | 20 | - | 0 | 0 |
| 4 | 9 | - | 41 | - | 20 | - | 33 | - |
| 4A | 14 | - | 44 | - | 0 | 0 | 33 | - |
| 4B | 34 | - | 44 | - | 0 | 0 | 33 | - |
| 4A-1 | 26 | - | 49 | - | 20 | - | 33 | - |
| 5 | 3 | - | 15 | - | 0 | 0 | 0 | 0 |
| 6 | - | 3 | 22 | - | 20 | - | 33 | - |
| 7 | 11 | - | 34 | - | 20 | - | 0 | 0 |
| 7A | 3 | - | 22 | - | 20 | - | 33 | 0 |
| 7B | 30 | - | 68 | - | 60 | - | 50 | - |
| 8 | 11 | - | 34 | - | 40 | - | 0 | 0 |

TABLE 5

Percentile Change of Wave Heights
Waves from Northeast

| Plan | Locale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Channel Mouth | | Tide Gage No. 2 | | Mid-Point of Channel | | Submarine Basin Channel | |
| | Red. | Incr. | Red. | Incr. | Red. | Incr. | Red. | Incr. |
| Base Test | - | - | - | - | - | - | - | - |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | - |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | - | 25 |

## PART V: CONCLUSIONS

67. From results of the Midway model study it was concluded that:

*a*. The principal prototype problem is caused by a water-surface differential between lagoon and ocean. The non-existence of an effective barrier between lagoon and ocean allows wave action on the atoll reef to sustain the differential between the lagoon and ocean waters. The plan-7 series is the only group of plans tested that involved the installation of an effective barrier between lagoon and ocean, and consequently constitutes the only group of improvement works that would solve adequately the navigation problems in the entrance channel.

*b*. Plan 7B is the best of all the plans tested, since it practically eliminates channel currents due to wave action, and provides the channel mouth fair protection from westerly storm waves.

*c*. Widening the channel from 400 ft to 800 or 1000 ft provides some lessening of navigation hazards by affording a wider fairway and more favorable current directions.

*d*. Breakwaters on the west side of the channel in combination with channel widening are undesirable because of the effects of these elements on the hydraulic gradient of the channel flows.

*e*. Spending beaches installed on the east side of the channel mouth are ineffective as wave-height reducing elements.

*f*. Plan 8 is a satisfactory plan relative to currents when waves are from the west, but is entirely unsatisfactory when waves are from the northeast.

TABLE 6

Summary of Velocity Observations -- Base Test and Plans as Shown
20-Ft x 830-Ft Waves from West and Northeast Directions

| Plan | 1 | 2 | 3 | 3A | 3B | 3C | 4 | 5 | 6 | 7 | 7A | 7B | 7C | 8 | 9 | 9A | 9B | 9C | 10 | 10A | 10B | 10C | 10D | 11 | 11A | 11B | 11C | 11D | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Primary Wave Height, 20 Ft - Waves from West Direction** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Base Test | 0.8 | 0.9 | 1.6 | | | | 1.6 | 1.5 | 3.4 | 4.0 | | | | 6.4 | 6.5 | | | | 7.9 | 5.8 | | | | 3.3 | 1.5 | 6.7 | | | | S | S | 0.6 | 1.2 | 1.2 | 1.2 | 1.9 | 1.3 | 1.8 | 3.8 | 2.9 | 4.5 | 9.4 |
| 1 | 1.0 | 1.3 | 2.1 | | | | 1.6 | 1.7 | 4.6 | 5.3 | | | | 9.2 | 8.4 | | | | 7.5 | 4.5 | 6.5 | 4.0 | | 1.5 | | 2.4 | 4.2 | 5.8 | | S | S | 0.7 | 1.6 | 1.8 | 1.5 | 2.3 | 1.2 | 1.8 | 5.7 | 1.7 | 5.1 | 10.1 |
| 1A | 0.9 | 1.3 | 2.1 | | | | 1.6 | 1.7 | 4.6 | 5.4 | | | | 9.1 | 8.5 | | | | 7.9 | 4.7 | 7.0 | 5.5 | | 1.9 | | 3.6 | 5.2 | 5.9 | | S | S | 0.7 | 1.6 | 1.8 | 1.4 | 2.2 | 1.1 | 0.9 | 5.9 | 1.4 | 5.3 | 9.4 |
| 2 | 0.9 | 1.2 | 2.0 | | | | 1.8 | 1.8 | 4.5 | 5.1 | | | | 8.8 | 8.5 | | | | 5.9 | 8.3 | 4.6 | 2.0 | | 3.9 | 6.4 | | 0.8 | 0.7 | 6.8 | S | S | 0.8 | 1.5 | 1.7 | 1.4 | 2.3 | 1.3 | 2.2 | 6.0 | | 1.5 | 9.8 |
| 3 | 1.2 | 1.5 | 2.2 | 2.2 | | | 2.3 | 1.9 | 4.0 | 4.5 | 4.2 | | | 7.0 | 7.0 | 7.5 | | | 7.6 | | 7.5 | | | 3.6 | | 7.8 | | | | S | S | 1.2 | 2.1 | 2.2 | 1.8 | 2.8 | 1.2 | 1.8 | 4.4 | 3.3 | 4.1 | 9.5 |
| 3A | 1.4 | 1.9 | 2.8 | 2.9 | 2.7 | | 2.3 | 2.1 | 4.2 | 5.2 | 5.1 | 4.5 | | 6.9 | 7.2 | 7.1 | 6.5 | | 7.0 | | 7.7 | 6.5 | | 3.7 | | 7.4 | | | | S | S | 1.4 | 2.4 | 2.6 | 2.3 | 3.9 | 1.2 | 2.3 | 4.5 | 4.2 | 4.8 | 9.6 |
| 3B | 1.3 | 2.2 | 2.9 | 3.1 | 3.0 | 3.3 | 2.5 | 2.6 | 4.7 | 5.7 | 5.7 | 6.0 | 3.6 | 6.4 | 7.4 | 7.6 | 7.6 | 5.3 | 5.3 | | 7.6 | 8.1 | 6.6 | 3.3 | | 6.3 | | | | S | S | 1.5 | 2.7 | 2.6 | 2.7 | 4.2 | 4.1 | 2.4 | 4.5 | 4.5 | 3.8 | 10.8 |
| 4 | 1.3 | 1.9 | 2.8 | 3.0 | 3.0 | 3.0 | 2.4 | 2.3 | 5.1 | 5.8 | 6.0 | 6.0 | 3.6 | 4.9 | 7.1 | 7.5 | 7.4 | 5.4 | 4.5 | | 7.6 | 9.2 | 6.7 | 3.5 | | 6.4 | | | | S | S | 1.9 | 2.6 | 2.6 | 2.6 | 3.7 | 3.1 | S | 4.3 | 4.9 | 5.0 | 10.8 |
| 4A | 1.6 | 2.6 | 3.8 | 3.7 | 3.7 | 3.7 | 2.8 | 2.8 | 6.5 | 6.7 | 7.8 | 7.6 | 6.7 | 8.9 | 9.0 | 9.2 | 8.5 | 7.0 | 8.6 | | 8.9 | 7.9 | 6.6 | 4.9 | | 8.7 | | | | S | S | 1.6 | 3.3 | 3.2 | 3.3 | 4.9 | 6.1 | S | S | 3.3 | 5.3 | 9.1 |
| 4A-1 | 1.7 | 2.5 | 3.8 | 3.7 | 3.7 | 3.6 | 2.8 | 2.9 | 6.6 | 6.7 | 7.3 | 7.6 | 6.9 | 8.6 | 9.0 | 9.3 | 8.4 | 6.9 | 9.2 | | 9.2 | 8.3 | 6.9 | 4.9 | | 9.6 | | | | S | S | 1.6 | 3.3 | 3.3 | 3.4 | 5.0 | 5.9 | S | S | 3.2 | 4.1 | 9.9 |
| 4B | 1.7 | 2.7 | 4.1 | 4.2 | 3.9 | 3.9 | 3.3 | 3.0 | 6.4 | 7.7 | 8.0 | 8.0 | 6.9 | 8.7 | 8.9 | 9.4 | 8.9 | 6.8 | 8.9 | | 9.3 | 9.0 | 6.9 | 7.2 | | 7.8 | | | | S | S | 2.0 | 3.3 | 3.3 | 4.3 | 5.3 | 6.0 | S | S | S | 5.3 | 7.8 |
| 5 | 0.8 | 1.1 | 1.9 | | | | 1.9 | 1.8 | 3.6 | 4.1 | | | | 6.7 | 6.7 | | | | 7.7 | 6.0 | | | | 3.4 | | 6.5 | | | | S | S | 0.7 | 1.4 | 1.5 | 1.4 | 2.1 | 1.1 | 2.4 | 3.8 | 2.5 | 3.1 | 4.8 |
| 6 | 0.9 | 1.3 | 2.2 | | | | 2.1 | 2.0 | 4.0 | 4.2 | | | | 6.7 | 7.7 | | | | 6.4 | 5.9 | | | | 4.3 | | 7.2 | | | | S | S | 1.1 | 1.7 | 2.0 | 1.7 | 2.4 | 0.9 | 3.6 | 4.2 | 3.6 | S | S |
| 7 | S | S | 0.3 | | | | 0.7 | 2.2 | 2.0 | 2.0 | | | | 2.9 | 2.7 | | | | 3.2 | 3.0 | | | | 1.9 | | 3.4 | | | | S | S | S | 0.4 | 0.6 | S | S | S | 2.4 | 3.9 | 2.3 | 4.7 | 4.3 |
| 7A | S | S | S | | | | 0.9 | 1.3 | 1.0 | 1.2 | | | | 1.3 | 1.0 | | | | 1.2 | 1.2 | | | | 1.6 | | 2.5 | | | | S | S | S | S | S | S | S | S | 2.2 | 4.6 | S | S | S |
| 7B | S | S | S | | | | S | S | S | 0.8 | | | | 1.3 | 1.2 | | | | 0.9 | 0.9 | | | | 0.9 | | 0.8 | | | | S | S | S | S | S | S | S | S | S | S | S | S | S |
| 8 | S | S | 0.4 | | | | 0.8 | 1.8 | 2.0 | 1.8 | | | | 3.0 | 3.6 | | | | 3.7 | 3.1 | | | | 1.9 | | 3.3 | | | | S | S | S | 0.4 | 0.6 | 0.3 | 0.5 | 0.4 | 2.6 | 3.7 | 3.3 | 3.9 | 9.3 |
| **Primary Wave Height, 20 Ft - Waves from Northeast Direction** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Base Test | 1.5 | 3.9 | 2.9 | | | | 2.9 | 2.7 | 4.7 | 4.9 | | | | 7.6 | 7.1 | | | | 6.3 | 7.0 | | | | 5.2 | | 5.8 | | | | 2.0 | 2.2 | 2.5 | 2.9 | 3.6 | 2.4 | 2.6 | 0.9 | 5.1 | 6.2 | 6.0 | 1.1 | 0.9 |
| 7 | S | S | 0.3 | | | | S | S | 0.6 | 0.8 | | | | 1.0 | 0.7 | | | | 0.6 | 1.0 | | | | 1.8 | | 1.8 | | | | S | S | S | S | S | 0.2 | 0.4 | S | S | S | S | S | S |
| 8 | | 2.5 | 4.4 | | | | 4.9 | 4.5 | 10.7 | 10.3 | | | | 21.2 | 19.9 | | | | 17.9 | 20.9 | | | | 15.9 | | 18.0 | | | | | | | | | | | | | | | | |

NOTES: Velocity observations in fps (prototype) to nearest 0.1 ft.
Currents of less than 0.2 fps are denoted by "S".
Waves from east direction reproduce storm conditions of 26 February 1945.
Waves from northeast direction reproduce wave dimensions for storm of 26 February 1945.
Locations of model observation stations are shown on plate 6.

TABLE I

Summary of Water-Surface Elevations and Velocity Observations at Stations Shown
Base Test and Plans as Shown
20-Ft x 810-Ft Waves from West and Northeast Directions

| Plan | Observations | 13 | 14 | 15 | 16 | 5 | 6 | 9 | 10 | 11 | 1 | 2 | 3 | 7 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Model Observation Station Number | | | | | | | | | | | | | | | |
| | | **Primary Wave Height, 20 Ft - Waves from West Direction** | | | | | | | | | | | | | | | |
| Base Test | A | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 0.4 | 0.0 | -0.2 | 1.3 | 1.3 | 1.2 | 1.0 | 0.4 | 0.0 | -0.2 |
| | B | S | S | 0.6 | 1.8 | 1.5 | 3.4 | 6.5 | 7.9 | 3.3 | 0.8 | 0.9 | 1.6 | 4.0 | 6.5 | 7.9 | 3.3 |
| 1 | A | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 | 0.7 | 0.1 | -0.8 | -0.6 | 1.3 | 1.2 | 1.1 | 0.6 | 0.1 | -0.8 | -0.6 |
| | B | S | S | 0.7 | 1.6 | 1.7 | 4.6 | 8.4 | 7.5 | 1.5 | 1.0 | 1.3 | 2.1 | 5.3 | 8.4 | 7.5 | 1.5 |
| 1A | A | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 | 0.7 | 0.0 | -0.8 | -0.5 | 1.3 | 1.2 | 1.1 | 0.6 | 0.0 | -0.8 | -0.5 |
| | B | S | S | 0.7 | 1.6 | 1.7 | 4.6 | 8.5 | 7.9 | 1.9 | 0.9 | 1.3 | 2.1 | 5.4 | 8.5 | 7.9 | 1.9 |
| 2 | A | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 | 0.6 | 0.0 | -0.4 | -0.3 | 1.3 | 1.2 | 1.0 | 0.5 | 0.0 | -0.4 | -0.3 |
| | B | S | S | 0.8 | 1.5 | 1.8 | 4.5 | 8.5 | 5.8 | 3.8 | 0.9 | 1.2 | 2.0 | 5.1 | 8.5 | 5.8 | 3.8 |
| 3 | A | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 | 0.7 | 0.3 | 0.0 | -0.2 | 1.3 | 1.3 | 1.1 | 0.6 | 0.3 | 0.0 | -0.2 |
| | B | S | S | 1.2 | 2.1 | 1.9 | 4.0 | 7.0 | 7.6 | 3.6 | 1.2 | 1.5 | 2.2 | 4.5 | 7.0 | 7.6 | 3.6 |
| 3A | A | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 | 0.7 | 0.3 | 0.0 | -0.2 | 1.2 | 1.2 | 1.0 | 0.7 | 0.3 | 0.0 | -0.2 |
| | B | S | S | 1.4 | 2.4 | 2.1 | 4.2 | 7.2 | 7.0 | 3.7 | 1.4 | 1.9 | 2.8 | 5.2 | 7.2 | 7.0 | 3.7 |
| 3B | A | 1.2 | 1.2 | 1.1 | 1.0 | 0.9 | 0.7 | 0.2 | 0.0 | -0.2 | 1.3 | 1.2 | 1.0 | 0.6 | 0.2 | 0.0 | -0.2 |
| | B | S | S | 1.5 | 2.7 | 2.6 | 4.7 | 7.4 | 5.3 | 3.3 | 1.3 | 2.2 | 2.9 | 5.7 | 7.4 | 5.3 | 3.3 |
| 4 | A | 1.2 | 1.2 | 1.1 | 1.0 | 0.9 | 0.6 | 0.2 | 0.0 | -0.2 | 1.3 | 1.2 | 1.0 | 0.6 | 0.2 | 0.0 | -0.2 |
| | B | S | S | 1.5 | 2.6 | 2.3 | 5.1 | 7.1 | 4.5 | 3.5 | 1.3 | 1.9 | 2.8 | 5.8 | 7.1 | 4.5 | 3.5 |
| 4A | A | 1.2 | 1.2 | 1.1 | 0.9 | 0.7 | 0.2 | -0.3 | -0.2 | -0.3 | 1.2 | 1.1 | 0.7 | 0.2 | -0.3 | -0.2 | -0.3 |
| | B | S | S | 1.6 | 3.3 | 2.8 | 6.5 | 9.0 | 8.6 | 4.9 | 1.6 | 2.6 | 3.8 | 6.7 | 9.0 | 8.6 | 4.9 |
| 4A-1 | A | 1.2 | 1.2 | 1.1 | 0.9 | 0.8 | 0.2 | -0.3 | -0.2 | -0.3 | 1.2 | 1.1 | 0.7 | 0.2 | -0.3 | -0.2 | -0.3 |
| | B | S | S | 1.6 | 3.3 | 2.9 | 6.6 | 9.0 | 8.2 | 4.9 | 1.7 | 2.5 | 3.8 | 6.7 | 9.0 | 8.2 | 4.9 |
| 4B | A | 1.2 | 1.2 | 1.1 | 0.9 | 0.8 | 0.2 | -0.4 | -0.5 | -0.4 | 1.2 | 1.1 | 0.6 | 0.0 | -0.4 | -0.5 | -0.4 |
| | B | S | S | 2.0 | 3.3 | 3.0 | 6.5 | 8.9 | 8.9 | 7.2 | 1.7 | 2.7 | 4.1 | 7.7 | 8.9 | 8.9 | 7.2 |
| 5 | A | 1.2 | 1.2 | 1.2 | 1.1 | 1.0 | 0.9 | 0.4 | 0.0 | -0.3 | 1.3 | 1.2 | 1.1 | 0.9 | 0.4 | 0.0 | -0.3 |
| | B | S | S | 0.7 | 1.4 | 1.8 | 3.6 | 6.7 | 7.7 | 3.4 | 0.8 | 1.1 | 1.9 | 4.1 | 6.7 | 7.7 | 3.4 |
| 6 | A | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 | 0.9 | 0.1 | 0.0 | -0.4 | 1.3 | 1.2 | 1.1 | 0.8 | 0.1 | 0.0 | -0.4 |
| | B | S | S | 1.1 | 1.7 | 2.0 | 4.0 | 7.7 | 6.4 | 4.3 | 0.9 | 1.3 | 2.2 | 4.2 | 7.7 | 6.4 | 4.3 |
| 7 | A | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | -0.3 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | -0.3 |
| | B | S | S | S | 0.4 | 2.2 | 2.0 | 2.7 | 3.2 | 1.8 | S | S | 0.3 | 2.0 | 2.7 | 3.2 | 1.8 |
| 7A | A | 0.0 | 0.0 | 0.0 | 0.0 | -0.04 | -0.06 | -0.08 | -0.1 | -0.3 | 0.0 | 0.0 | 0.0 | -0.06 | -0.08 | -0.08 | -0.09 |
| | B | S | S | S | S | 1.3 | 1.0 | 1.0 | 1.2 | 1.6 | S | S | S | 1.2 | 1.0 | 1.2 | 1.6 |
| 7B | A | | | | | | | | | | | | | | | | |
| | B | S | S | S | S | S | S | 1.2 | 0.9 | 0.9 | S | S | S | 0.8 | 1.2 | 0.9 | 0.9 |
| 8 | A | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | -0.3 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | -0.3 |
| | B | S | S | S | 0.4 | 1.8 | 2.0 | 3.6 | 3.7 | 1.9 | S | S | 0.4 | 1.8 | 3.6 | 3.7 | 1.9 |
| | | **Primary Wave Height, 20 Ft - Waves from Northeast Direction** | | | | | | | | | | | | | | | |
| Base Test | A | 0.9 | 0.9 | 1.0 | 0.9 | 0.8 | 0.5 | 0.2 | 0.0 | -0.2 | 0.9 | 0.8 | 0.7 | 0.4 | 0.2 | 0.0 | -0.2 |
| | B | 2.0 | 2.1 | 2.5 | 2.9 | 2.7 | 4.7 | 7.1 | 6.3 | 5.2 | 1.5 | 3.9 | 2.9 | 4.9 | 7.1 | 6.3 | 5.2 |
| 7 | A | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.01 | -0.1 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | -0.1 |
| | B | S | S | S | S | S | 0.6 | 0.7 | 0.6 | 1.8 | S | S | S | 0.8 | 0.7 | 0.6 | 1.8 |
| 8 | A | 5.0 | 5.0 | 4.9 | 4.6 | 4.4 | 3.2 | 0.0 | 0.8 | -0.7 | 5.0 | 4.7 | 4.6 | 3.2 | 0.0 | 0.8 | -0.7 |
| | B | | | | | 4.5 | 10.7 | 13.9 | 17.9 | 15.9 | | 4.5 | 4.4 | 10.3 | 19.9 | 17.9 | 15.9 |

NOTES: A = Water-surface elevations in ft (prototype) to nearest 0.1 ft above mean lower low water unless otherwise indicated by minus sign.
B = Velocity observations in fps (prototype) to nearest 0.1 ft.
Currents of less than 0.2 fps are denoted by "S".
Waves from west direction reproduce storm conditions of [illegible] February 1965.
Waves from northeast direction reproduce wave dimensions for storm of [illegible] February 1965.
Locations of model observation stations are shown on plate 6.

TABLE 8

Summary of Wave-Height Observations -- Base Test and Plans as Shown

| Plan | Model Gage Number | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| **Primary Wave Height, 20 Ft - Waves from West Direction** | | | | | | | | | | | | | | | | | | | |
| Base Test | 3.5 | 8.5 | 8.5 | 7.5 | 7.0 | 7.0 | 8.0 | 8.0 | 8.5 | 6.5 | 5.0 | 4.5 | 2.0 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1 | 8.0 | 9.0 | 8.0 | 7.0 | 6.5 | 6.5 | 8.0 | 8.0 | 8.5 | 6.0 | 6.5 | 3.0 | 1.5 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 1A | 9.5 | 9.0 | 9.0 | 7.5 | 7.0 | 6.5 | 7.0 | 7.5 | 8.0 | 5.0 | 6.0 | 3.0 | 1.5 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 2 | 8.0 | 3.0 | 9.0 | 7.5 | 6.0 | 4.5 | 5.0 | 4.5 | 9.0 | 4.5 | 3.0 | 2.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 3 | 8.0 | 8.0 | 8.5 | 7.0 | 6.5 | 6.5 | 6.5 | 6.5 | 8.5 | 5.5 | 4.0 | 2.0 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 |
| 3A | 9.5 | 8.5 | 8.5 | 7.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.5 | 5.5 | 3.5 | 2.0 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 |
| 3B | 9.0 | 8.5 | 8.0 | 7.0 | 7.0 | 7.0 | 6.0 | 6.0 | 8.0 | 5.5 | 3.5 | 2.0 | 1.5 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| 4 | 9.5 | 9.5 | 8.0 | 7.0 | 7.0 | 7.0 | 6.5 | 6.0 | 3.0 | 5.0 | 3.0 | 2.0 | 1.5 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 |
| 4A | 8.0 | 2.0 | 9.0 | 7.0 | 7.0 | 6.0 | 6.5 | 6.5 | 8.0 | 4.5 | 3.0 | 2.5 | 1.5 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 4A-1 | 8.0 | 8.0 | 9.0 | 7.0 | 6.5 | 5.5 | 5.5 | 5.0 | 7.5 | 4.0 | 3.0 | 2.0 | 1.5 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 4B | 9.0 | 9.0 | 9.0 | 7.0 | 6.0 | 5.0 | 5.0 | 4.0 | 9.5 | 4.5 | 3.0 | 2.5 | 1.5 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 5 | 9.5 | 9.0 | 8.5 | 8.0 | 6.5 | 7.5 | 9.0 | 7.5 | 9.0 | 6.5 | 5.0 | 2.5 | 2.0 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| 6 | 9.0 | 8.5 | 9.0 | 7.5 | 7.5 | 7.0 | 8.0 | 8.5 | 9.0 | 6.0 | 4.5 | 2.0 | 1.5 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 |
| 7 | 9.5 | 9.0 | 8.5 | 7.5 | 7.5 | 7.5 | 6.0 | 6.0 | 8.0 | 5.0 | 4.0 | 2.0 | 2.0 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| 7A | 9.5 | 8.5 | 8.0 | 7.5 | 7.0 | 7.0 | 9.0 | 7.5 | 8.0 | 6.5 | 4.0 | 2.0 | 1.5 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 |
| 7B | 9.5 | 9.0 | 9.5 | 7.0 | 6.0 | 6.5 | 4.5 | 4.0 | 3.5 | 3.0 | 1.5 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8 | 9.0 | 9.5 | 8.0 | 7.0 | 7.5 | 7.5 | 6.0 | 6.0 | 8.0 | 5.0 | 4.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| **Primary Wave Height, 20 Ft - Waves from Northeast Direction** | | | | | | | | | | | | | | | | | | | |
| Base Test | 3.5 | 4.0 | 3.5 | 4.0 | 4.0 | 4.0 | 2.5 | 3.0 | 3.5 | 2.0 | 1.0 | 1.0 | 1.5 | 2.0 | 2.0 | 1.5 | 1.0 | 1.0 | 1.0 |
| 7 | 3.5 | 3.5 | 3.5 | 4.0 | 4.0 | 4.0 | 3.0 | 2.5 | 4.0 | 2.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8 | 3.5 | 3.5 | 3.5 | 4.5 | 4.0 | 4.5 | 2.5 | 3.0 | 4.0 | 2.0 | 1.0 | 1.0 | 1.5 | 2.5 | 2.5 | 1.5 | 1.0 | 1.0 | 1.0 |

NOTES: Wave heights in ft (prototype) to nearest 0.5 ft.
Gages 2 and 3 were used for measuring wave heights during model adjustment tests.
Waves from west direction reproduce storm conditions of 26 February 1945.
Waves from northeast direction reproduce wave dimensions for storm of 26 February 1945.
Locations of model gages are shown on plate 37.

# TABLE 9

## Summary of Observations on Wave-Height Lagoon-Head Relations
## Base Test Conditions

### Primary Wave Characteristics as Shown - Waves from West Direction

| Primary Wave Characteristics | | | | Water-Surface Elevations In Ft Above MLLW | | Current Magnitudes in Ft Per Sec | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Model Observation Station Number | | | | | | | | | | | |
| Height Ft | Period Sec | Length Ft | Water Depth Ft | Gage 1 | Gage 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 10A | 11 | 11B |
| 5 | 15 | 830 | 120 | 0.15 | 0.0 | 0.4 | 0.8 | 0.8 | 0.7 | 1.3 | 1.4 | 2.0 | 1.7 | 1.8 | 1.9 | 0.9 | 2.0 |
| 10 | 15 | 830 | 120 | 0.55 | 0.0 | 1.1 | 2.0 | 1.9 | 1.9 | 3.3 | 3.7 | 5.3 | 5.3 | 5.4 | 5.2 | 3.2 | 5.0 |
| 15 | 15 | 830 | 120 | 0.9 | 0.0 | 0.8 | 1.8 | 1.5 | 1.4 | 3.2 | 3.6 | 6.1 | 5.9 | 7.0 | 5.2 | 3.6 | 7.5 |
| 20 | 15 | 830 | 120 | 1.2 | 0.0 | 0.9 | 1.6 | 1.6 | 1.5 | 3.4 | 4.0 | 6.4 | 6.5 | 7.9 | 5.8 | 3.3 | 6.7 |
| 30 | 15 | 830 | 120 | 1.8 | 0.27 | 1.5 | 2.2 | 2.2 | 2.2 | 3.9 | 4.8 | 7.5 | 7.1 | 9.1 | 7.8 | 4.7 | 9.2 |

NOTES: All observations shown are in prototype values.
Locations of model observation stations are shown on plate 6.

# PHOTOGRAPHS

Surface current patterns, 20-ft waves from west direction
Base test conditions

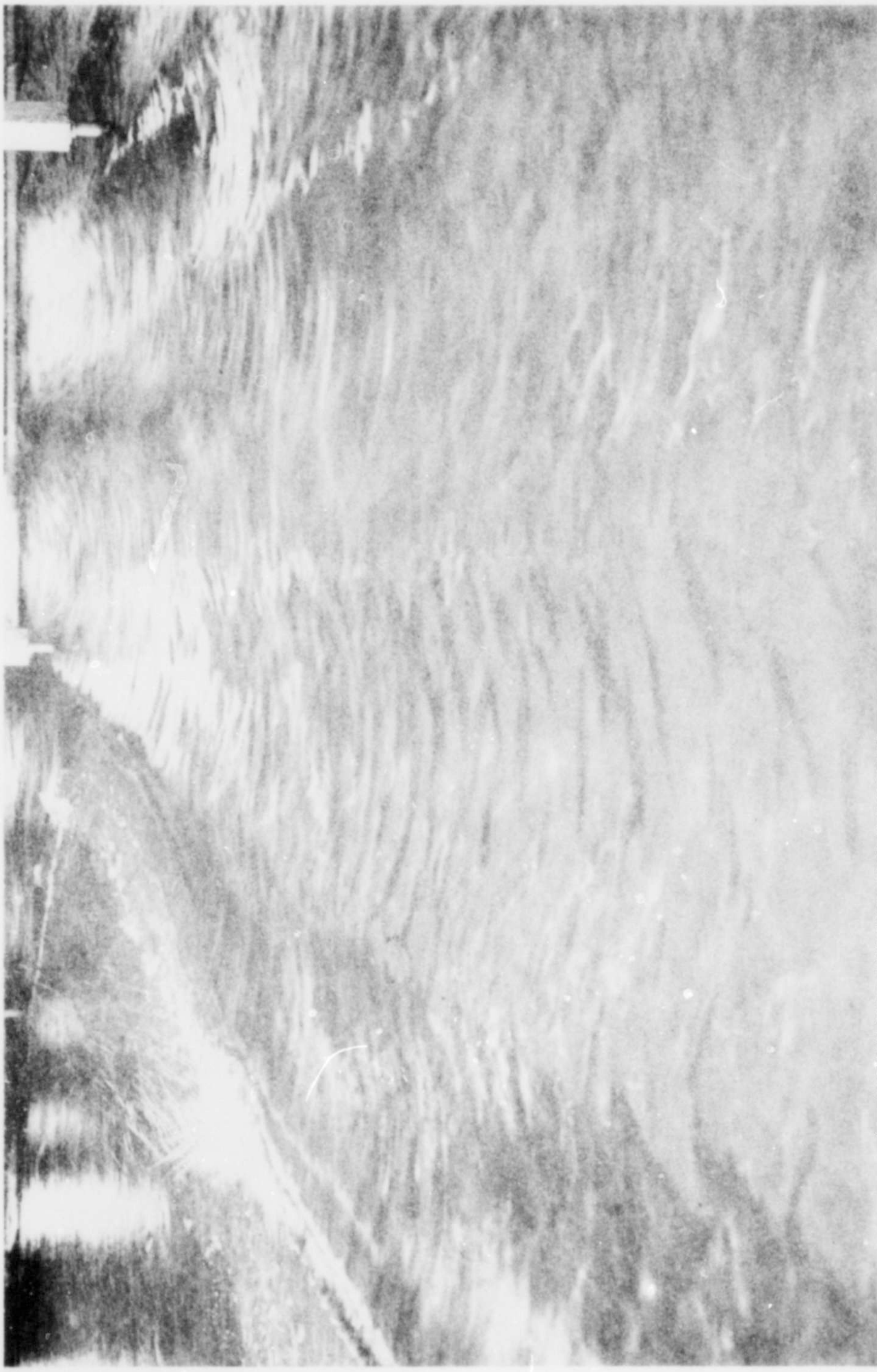
PHOTOGRAPH 1

Wave patterns at channel mouth, 20-ft waves from west direction
Base test conditions

PHOTOGRAPH 2

Surface current patterns, 20-ft waves from northeast direction
Base test conditions

PHOTOGRAPH 3



Waves breaking on northeast reef

PHOTOGRAPH 4


Surface current patterns, 20-ft waves from west direction
Plan 2 installed

PHOTOGRAPH 5

Wave patterns at channel mouth, 20-ft waves from west direction
Plan 2 installed

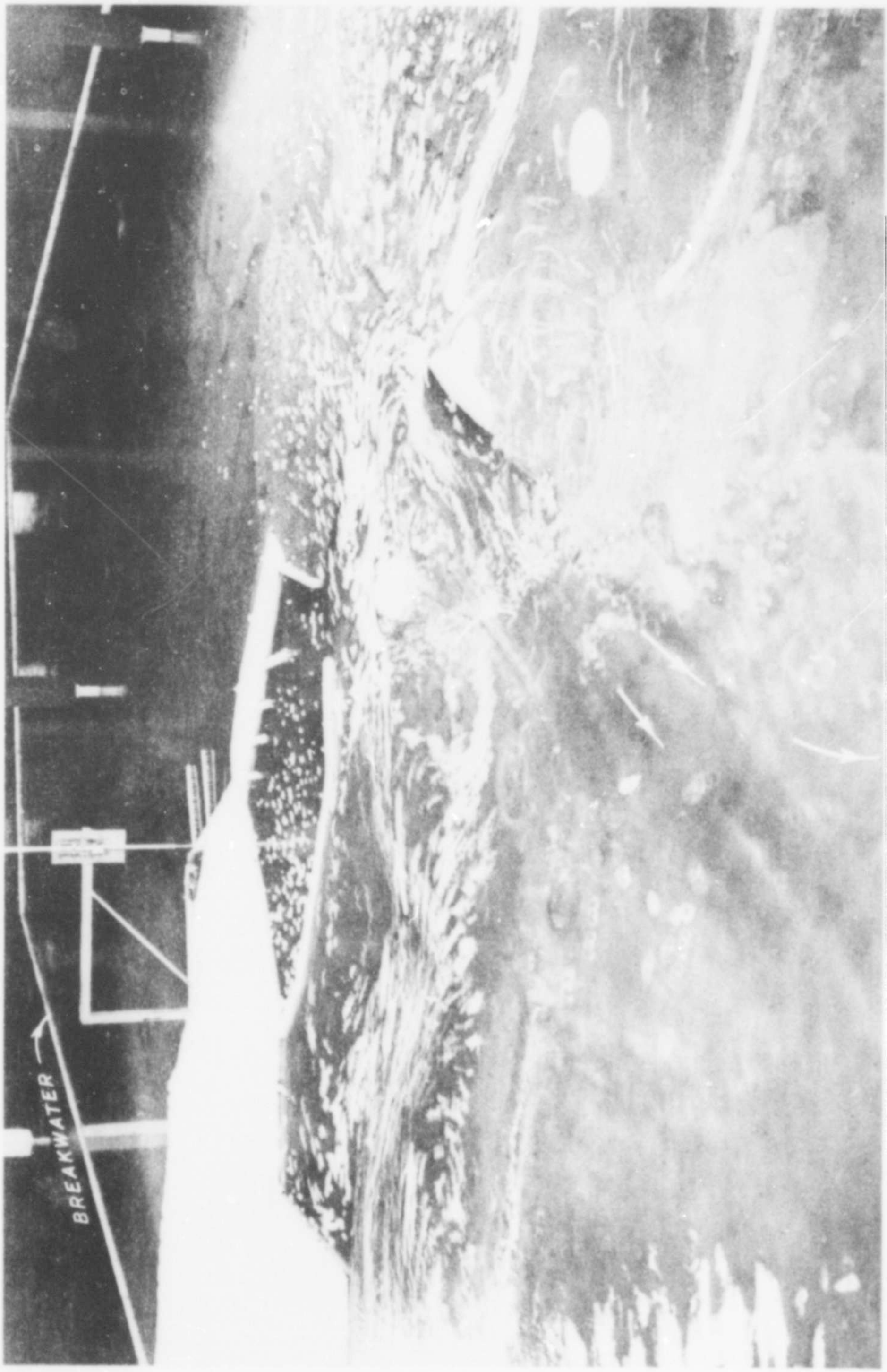
PHOTOGRAPH 6

Surface current patterns, 20-ft waves from west direction
Plan 4B installed

PHOTOGRAPH 7

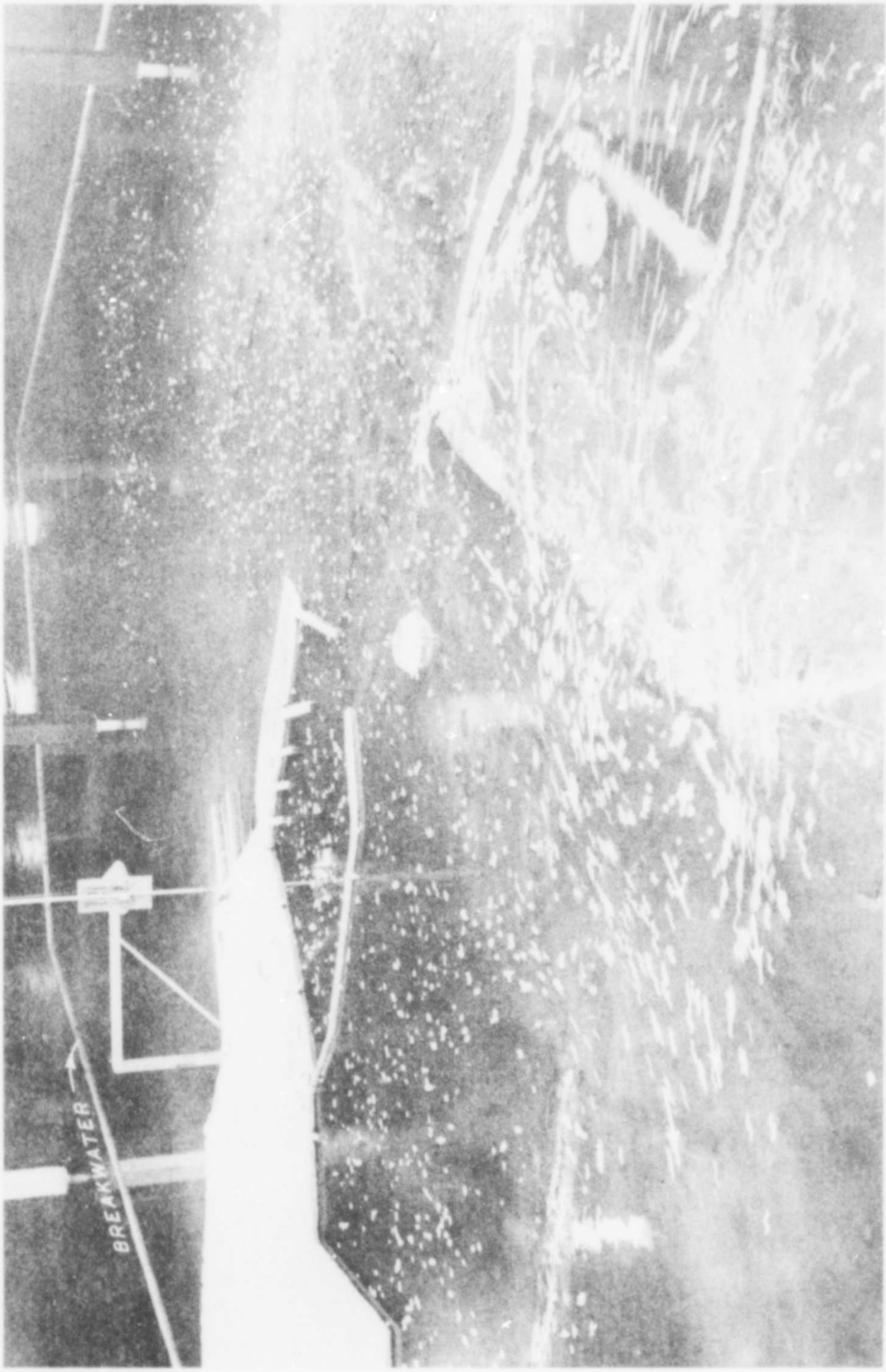

Wave patterns at channel mouth, 20-ft waves from west direction
Plan 4B installed

PHOTOGRAPH 8




Surface current patterns, 20-ft waves from west direction
Plan 7 installed

PHOTOGRAPH 9




Surface current patterns, 20-ft waves from northeast direction
Plan 7 Installed

PHOTOGRAPH 10


Surface current patterns, 20-ft waves from west direction
Plan 7B Installed

PHOTOGRAPH 11


Wave patterns at channel mouth, 20-ft waves from west direction
Plan 7B installed.

PHOTOGRAPH 12

Surface current patterns, 20-ft waves from west direction
Plan 8 installed

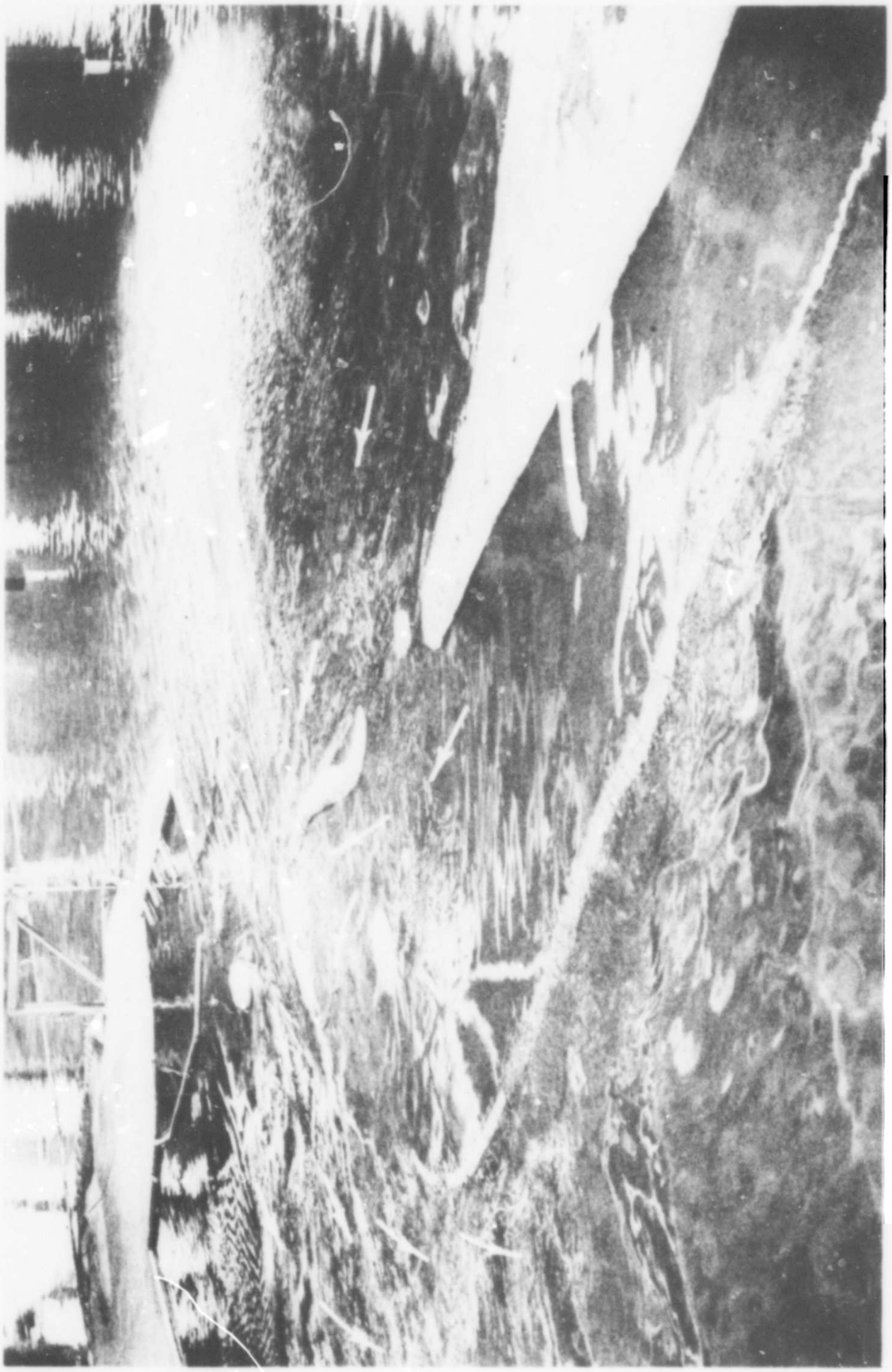
PHOTOGRAPH 13

Wave patterns at channel mouth, 20-ft waves from west direction
Plan 8 installed

PHOTOGRAPH 14

Surface current patterns, 20-ft waves from northeast direction
Plan 8 installed

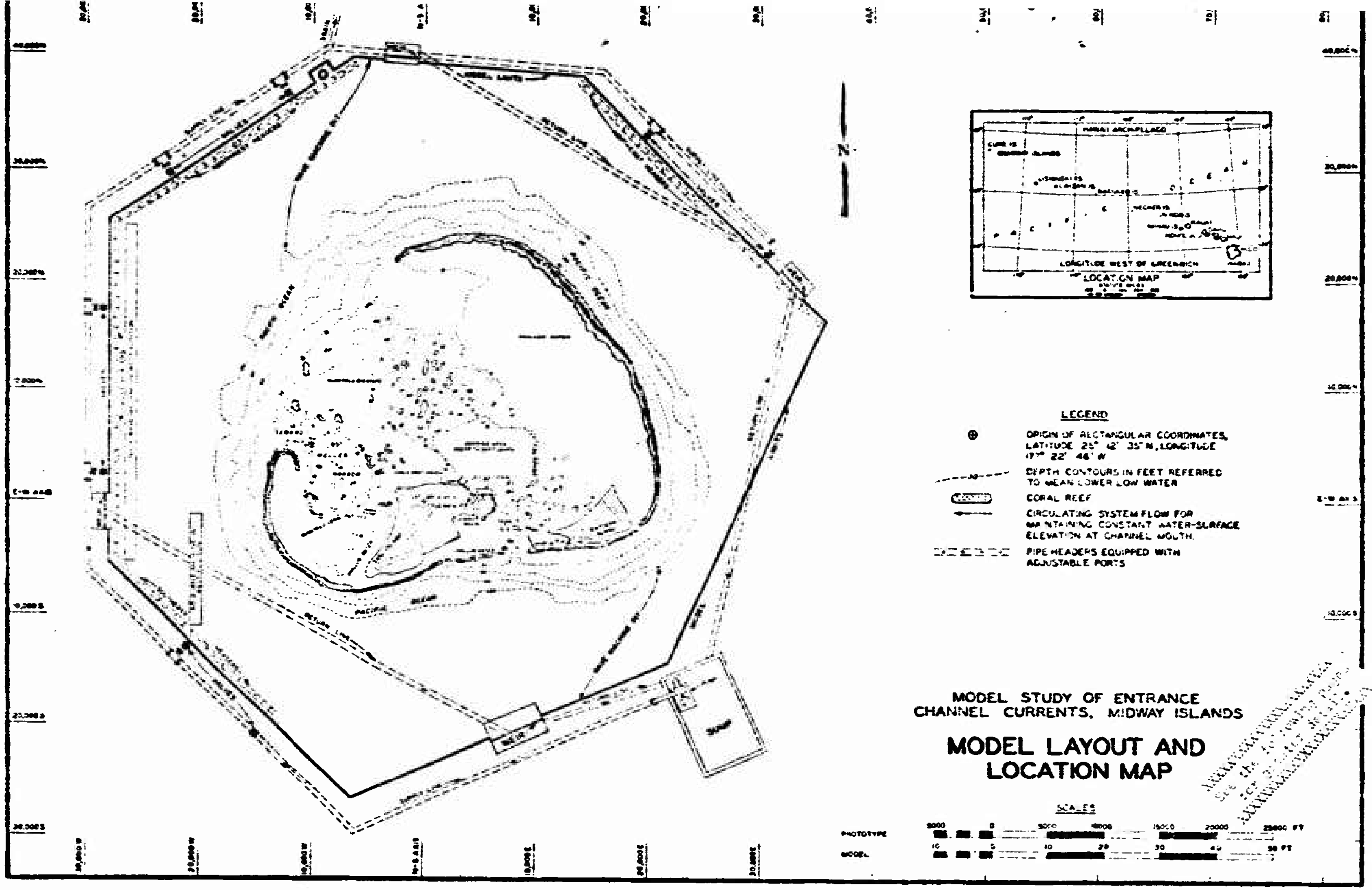
PHOTOGRAPH 15



Entrance channel flow conditions, 20-ft waves from northeast direction
Plan 8 installed

PHOTOGRAPH 16

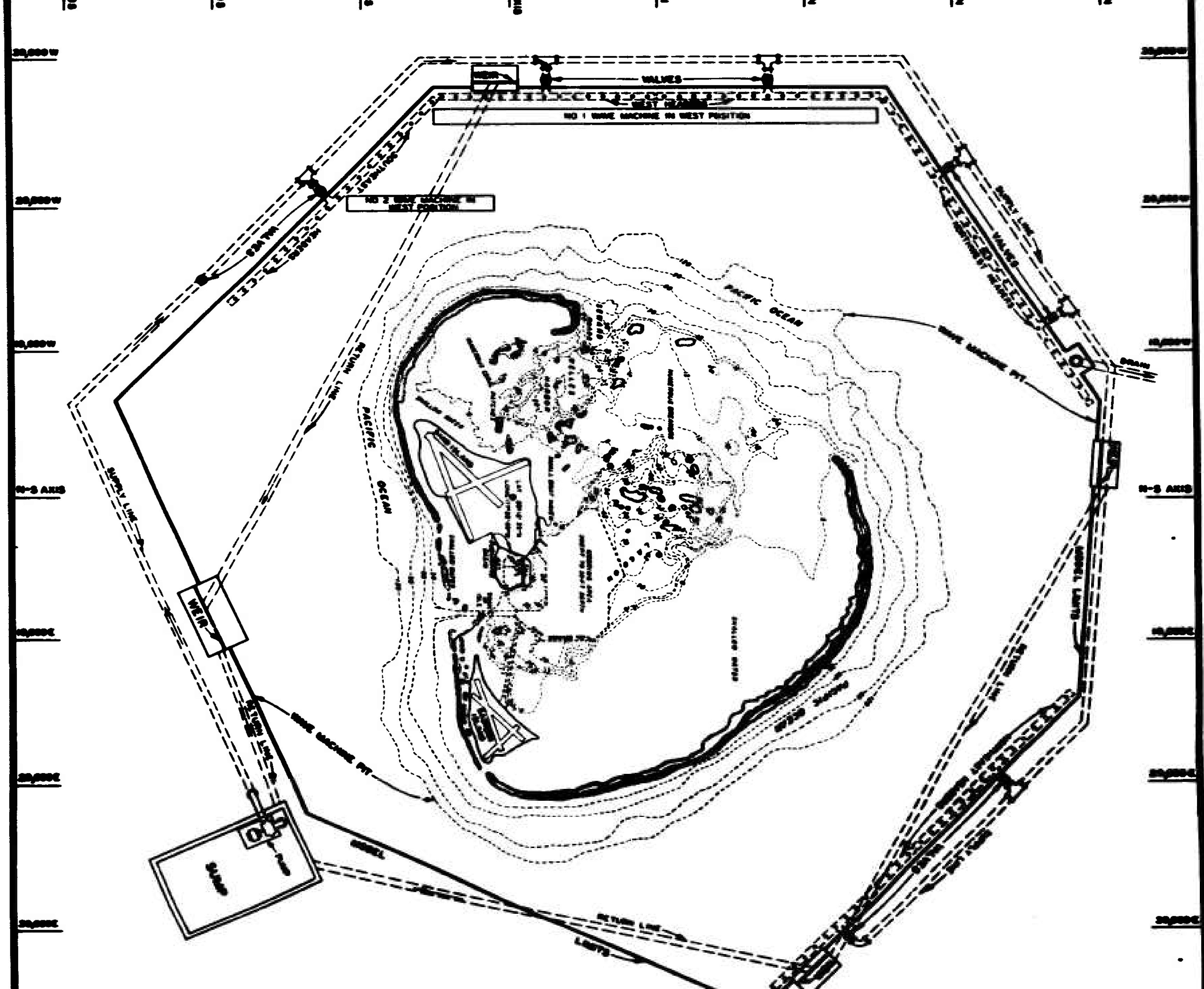
# PLATES



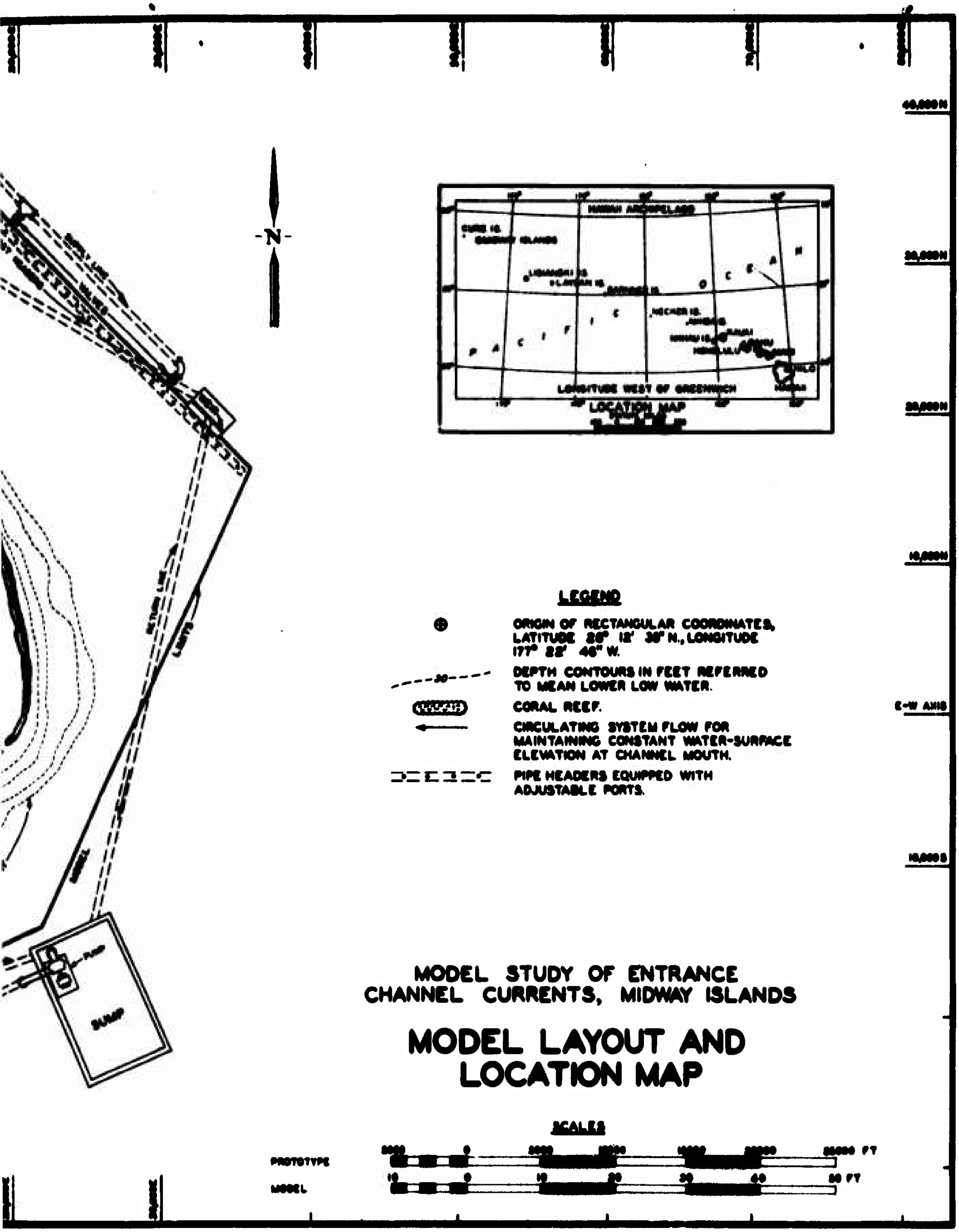

MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

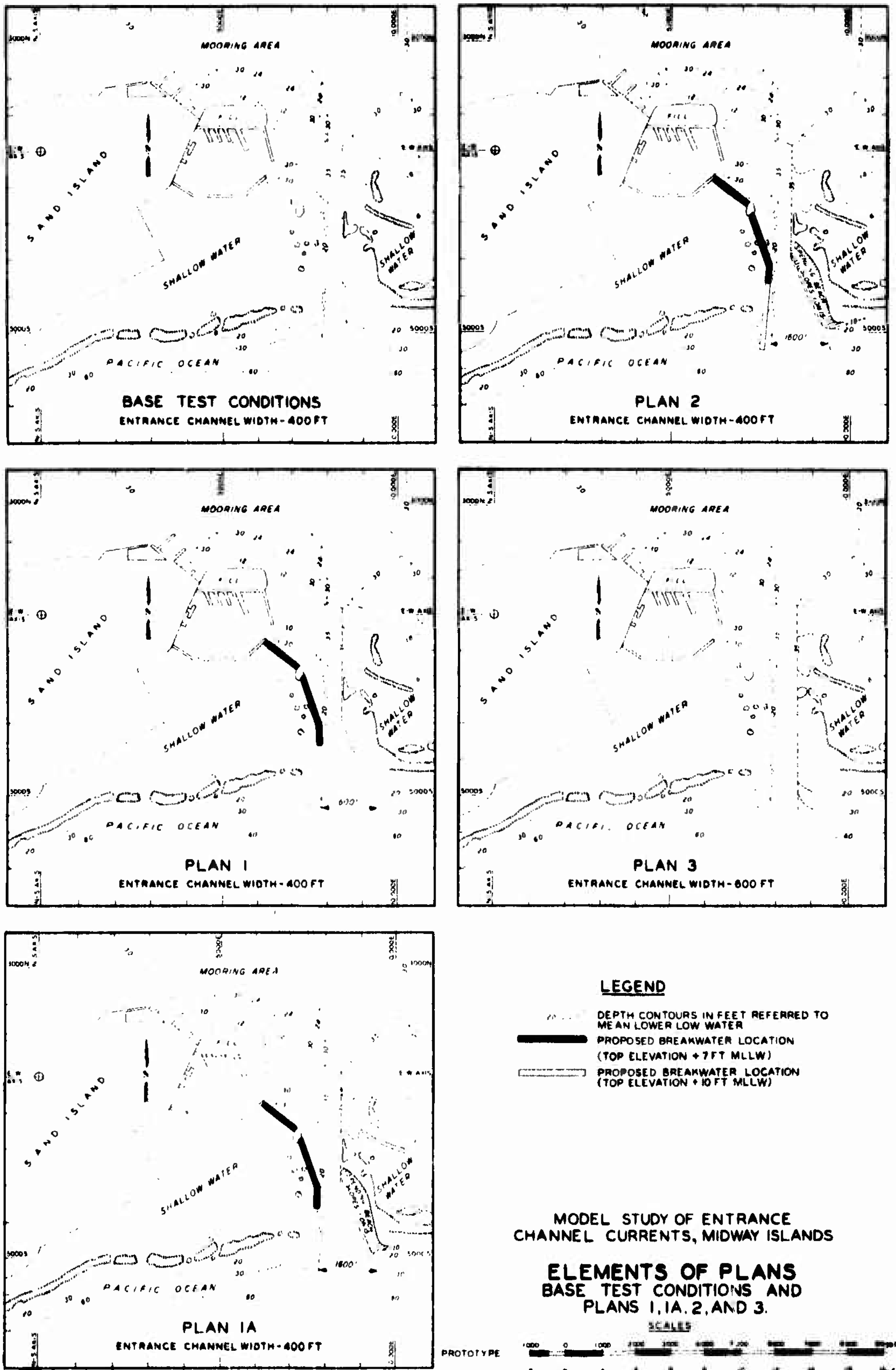
# MODEL LAYOUT AND LOCATION MAP

PLATE 1



VALVES
WEST HEADERS
NO 1 WAVE MACHINE IN WEST POSITION
NO 2 WAVE MACHINE IN WEST POSITION
N-S AXIS
N-S AXIS
WEIR
WEIR
WEIR
SUMP
RETURN LINE
RETURN LINE
SUPPLY LINE
SUPPLY LINE
VALVES
VALVES
HEADERS
SOUTHEAST
WAVE MACHINE PIT
WAVE MACHINE PIT
PACIFIC OCEAN
PACIFIC OCEAN
MODEL LIMITS
DRAIN


40,000 N
30,000 N
20,000 N
10,000 N
E-W AXIS
10,000 S
-N-
LOCATION MAP
LONGITUDE WEST OF GREENWICH
O C E A N
P A C I F I C
LEGEND
ORIGIN OF RECTANGULAR COORDINATES, LATITUDE 28° 12' 30" N., LONGITUDE 177° 22' 46" W.
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER.
CORAL REEF.
CIRCULATING SYSTEM FLOW FOR MAINTAINING CONSTANT WATER-SURFACE ELEVATION AT CHANNEL MOUTH.
PIPE HEADERS EQUIPPED WITH ADJUSTABLE PORTS.
SUMP
PUMP
MODEL
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
MODEL LAYOUT AND LOCATION MAP
SCALES
PROTOTYPE
MODEL
0
10
20
30
40
50 FT




**LEGEND**

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

PROPOSED BREAKWATER LOCATION (TOP ELEVATION + 7 FT MLLW)

PROPOSED BREAKWATER LOCATION (TOP ELEVATION + 10 FT MLLW)

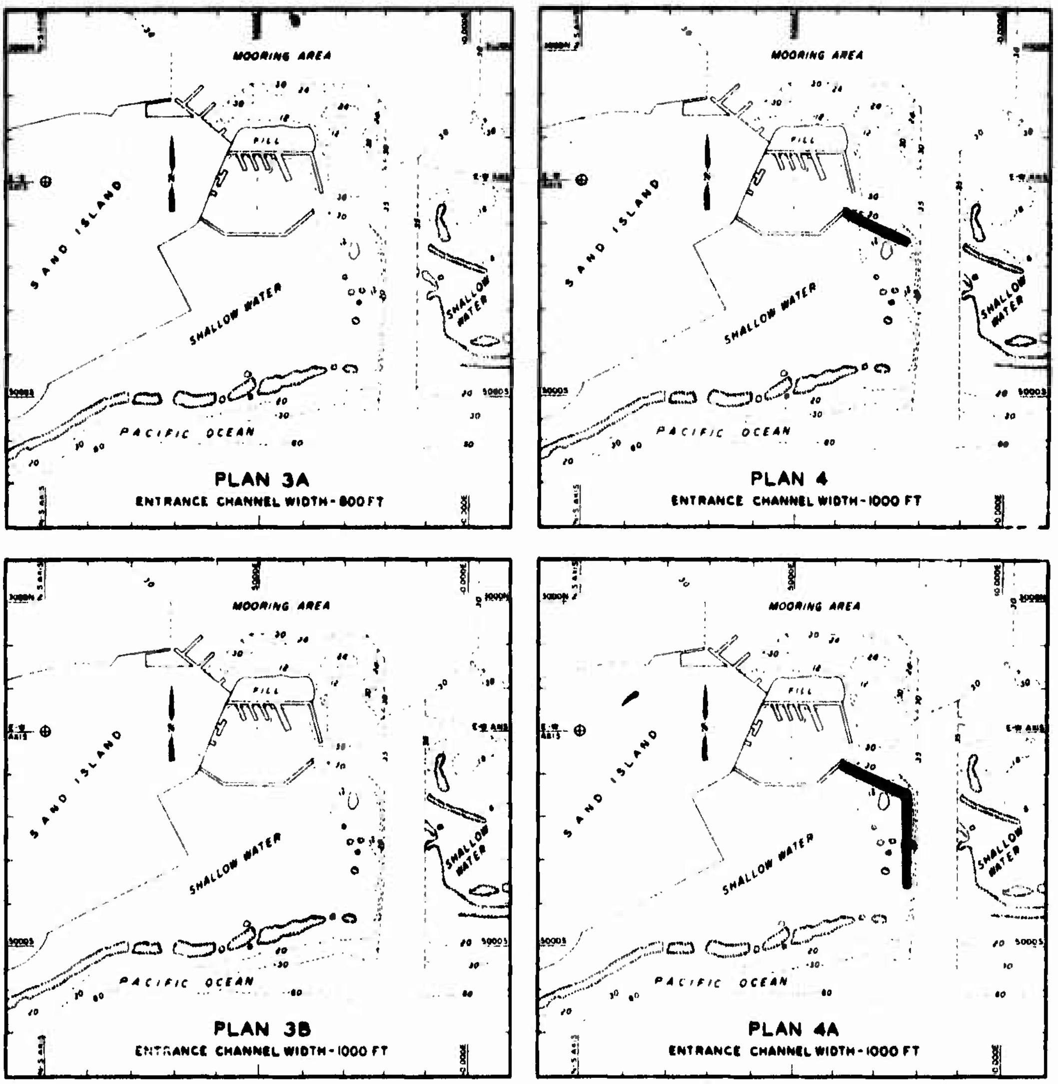
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

**ELEMENTS OF PLANS**
**BASE TEST CONDITIONS AND PLANS 1, 1A, 2, AND 3.**

SCALES

PROTOTYPE

MODEL




**LEGEND**

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

PROPOSED BREAKWATER LOCATION (TOP ELEVATION + 7 FT MLLW)

MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

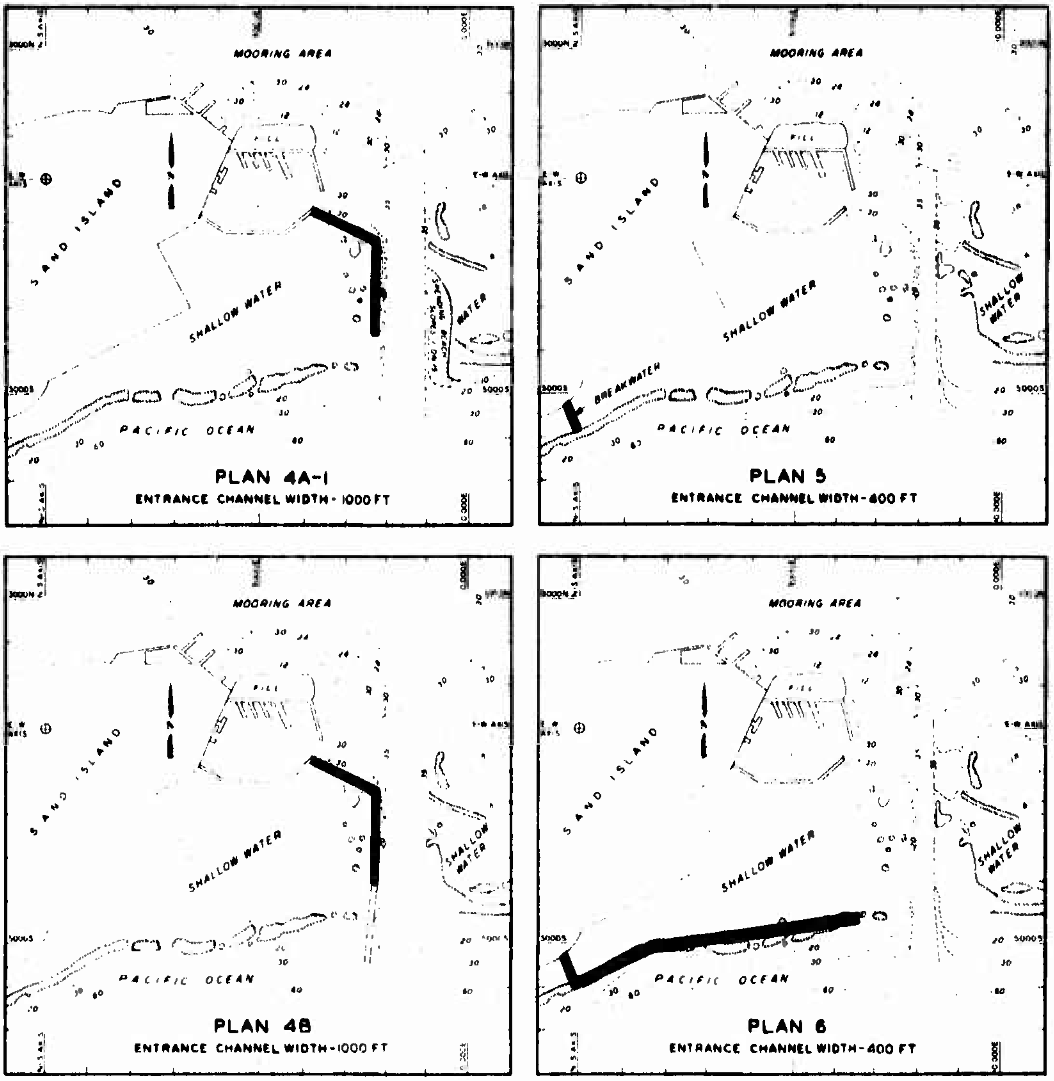
**ELEMENTS OF PLANS**

**PLANS 3A, 3B, 4, AND 4A**

SCALES

PROTOTYPE

MODEL




LEGEND

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

PROPOSED BREAKWATER LOCATION (TOP ELEVATION +10 FT MLLW)

MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

ELEMENTS OF PLANS

PLANS 4A-1, 4B, 5, AND 6

SCALES

PROTOTYPE

MODEL

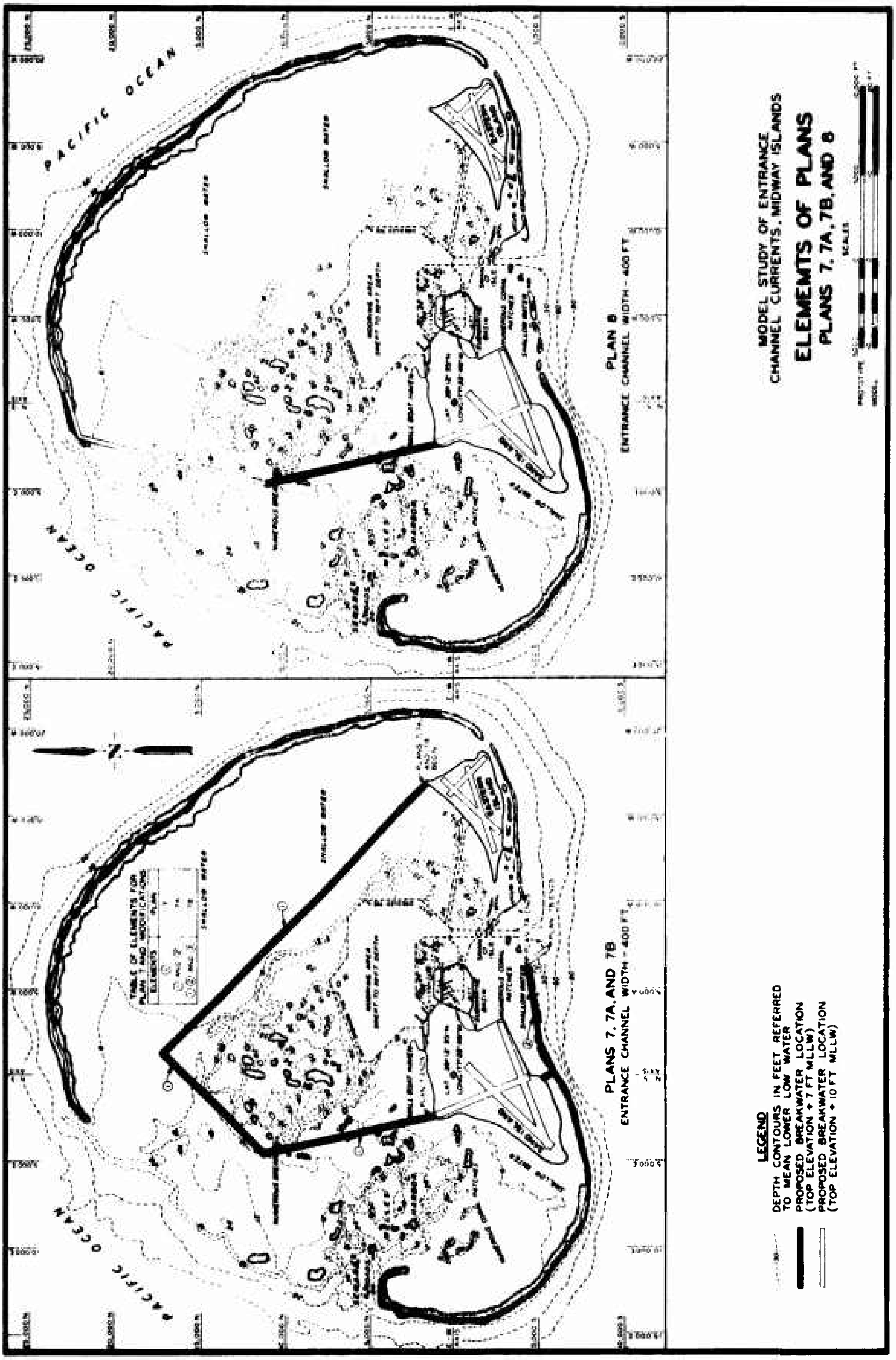

PACIFIC OCEAN
PACIFIC OCEAN
SHALLOW WATER
PLAN 8
ENTRANCE CHANNEL WIDTH - 400 FT
PLANS 7, 7A, AND 7B
ENTRANCE CHANNEL WIDTH - 400 FT
TABLE OF ELEMENTS FOR PLAN 7 AND MODIFICATIONS
LEGEND
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION (TOP ELEVATION + 7 FT MLLW)
PROPOSED BREAKWATER LOCATION (TOP ELEVATION + 10 FT MLLW)
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
ELEMEMTS OF PLANS
PLANS 7, 7A, 7B, AND 8
SCALES

PLATE 5

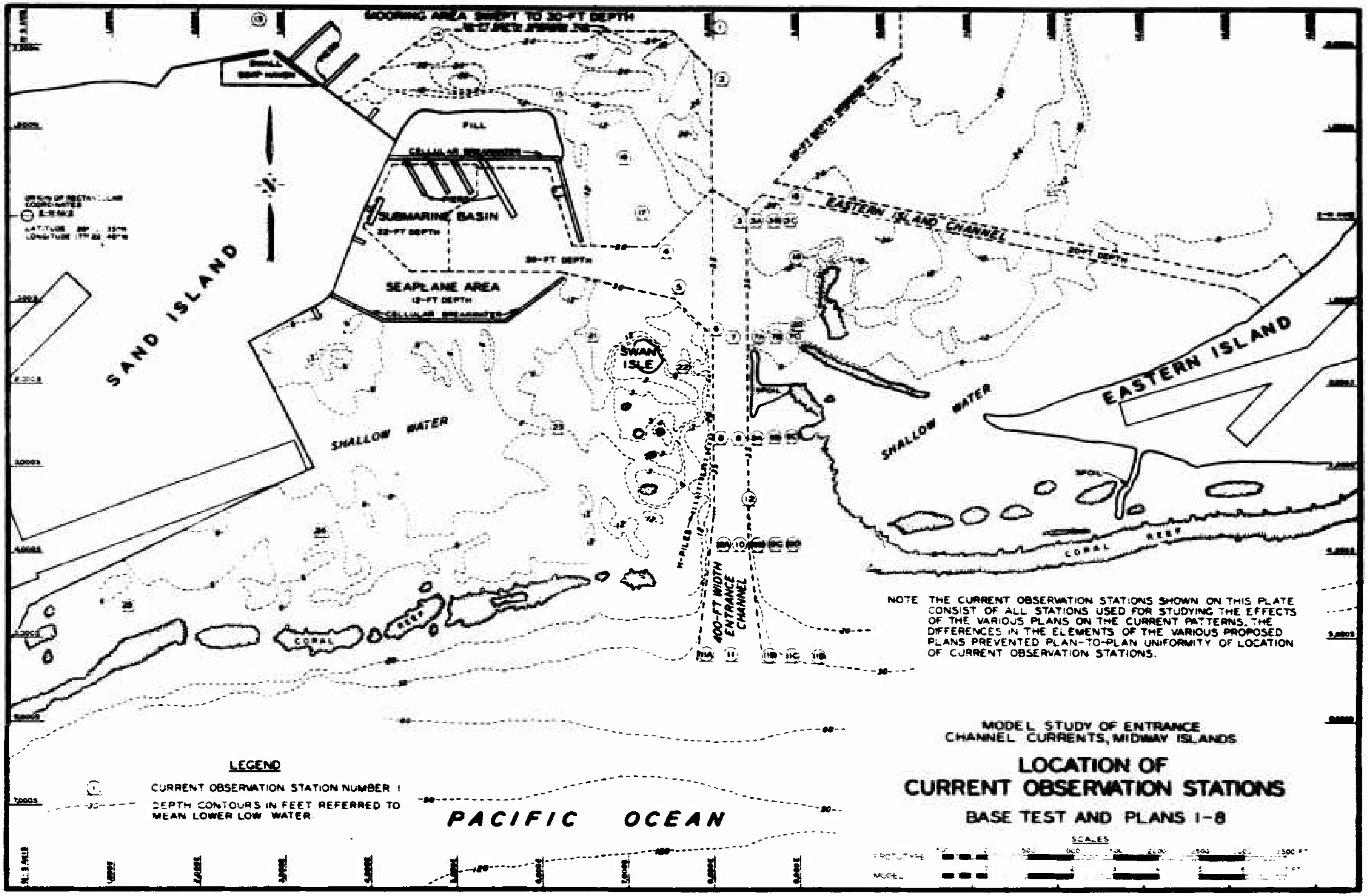
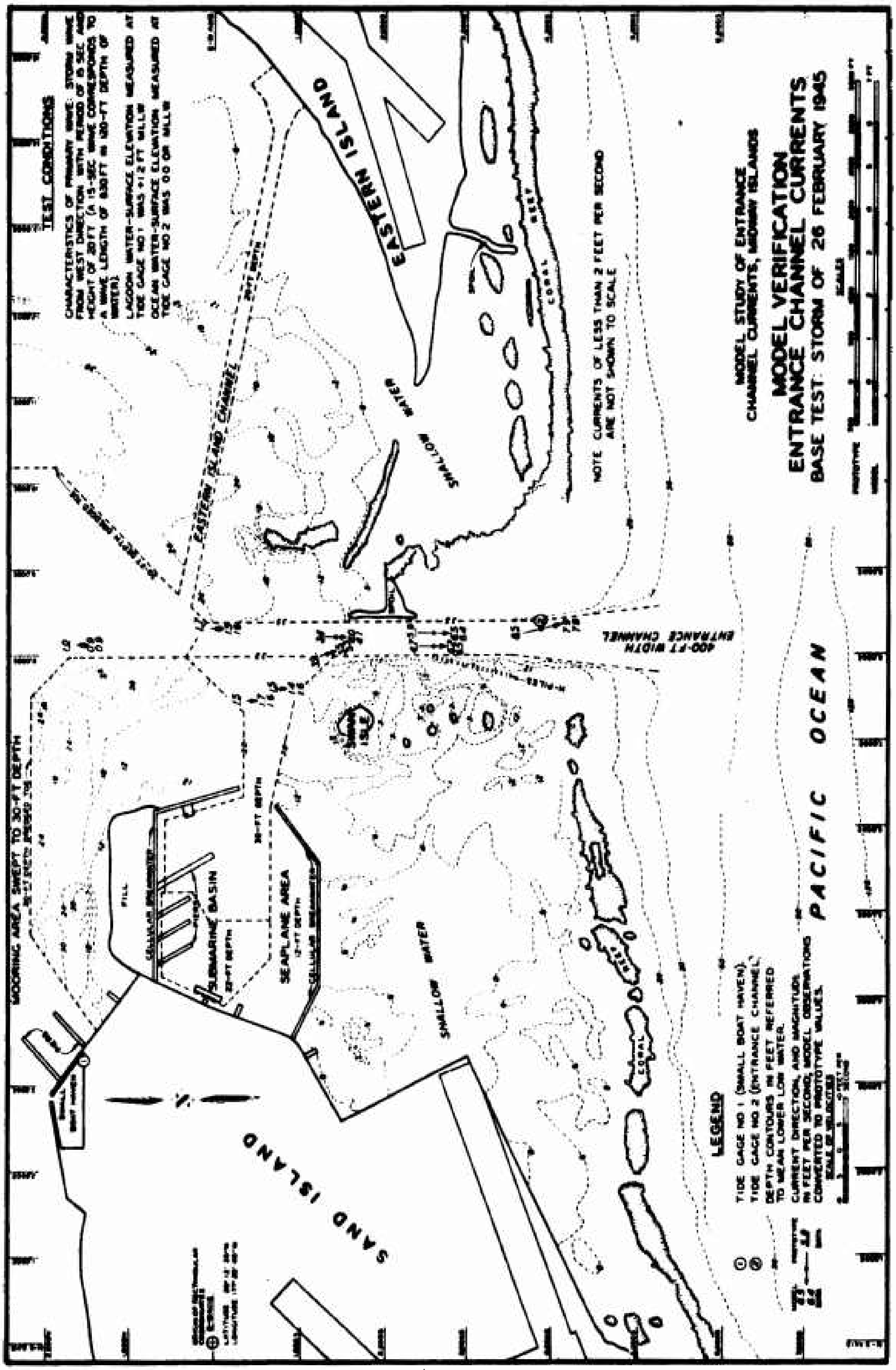
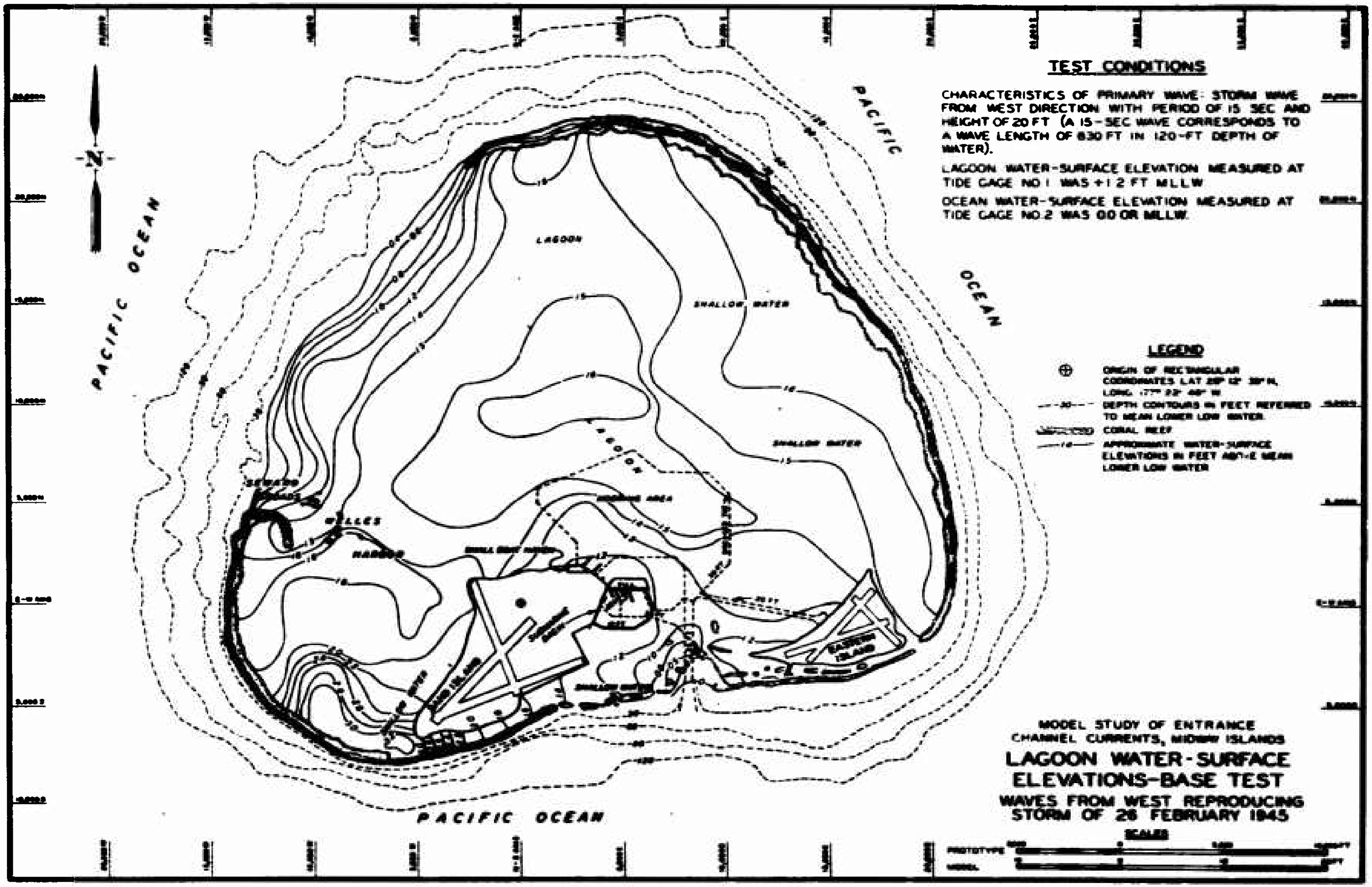

MOORING AREA SWEPT TO 30-FT DEPTH
SMALL BOAT HARBOR
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SHALLOW WATER
SWAN ISLE
EASTERN ISLAND CHANNEL
20-FT DEPTH
EASTERN ISLAND
SHALLOW WATER
SPOIL
CORAL REEF
H-PILES
400-FT WIDTH ENTRANCE CHANNEL
CORAL REEF
NOTE THE CURRENT OBSERVATION STATIONS SHOWN ON THIS PLATE CONSIST OF ALL STATIONS USED FOR STUDYING THE EFFECTS OF THE VARIOUS PLANS ON THE CURRENT PATTERNS. THE DIFFERENCES IN THE ELEMENTS OF THE VARIOUS PROPOSED PLANS PREVENTED PLAN-TO-PLAN UNIFORMITY OF LOCATION OF CURRENT OBSERVATION STATIONS.
LEGEND
CURRENT OBSERVATION STATION NUMBER 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
LOCATION OF CURRENT OBSERVATION STATIONS
BASE TEST AND PLANS 1-8
SCALES
PROTOTYPE
MODEL

PLATE 6



MOORING AREA SWEPT TO 30-FT DEPTH
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
PIERS
SUBMARINE BASIN
22-FT DEPTH
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
SAND ISLAND
EASTERN ISLAND CHANNEL
20-FT DEPTH
EASTERN ISLAND
SPIT ISLE
SHALLOW WATER
SPOIL
CORAL REEF
400-FT WIDTH ENTRANCE CHANNEL
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN).
TIDE GAGE NO 2 (ENTRANCE CHANNEL).
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER.
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES.
SCALE OF VELOCITIES
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
MODEL VERIFICATION
ENTRANCE CHANNEL CURRENTS
BASE TEST: STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


PLATE 7


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW.
LEGEND
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CORAL REEF
APPROXIMATE WATER-SURFACE ELEVATIONS IN FEET ABOVE MEAN LOWER LOW WATER
PACIFIC OCEAN
PACIFIC
OCEAN
LAGOON
SHALLOW WATER
WELLES
HARBOR
EASTERN ISLAND
N
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
LAGOON WATER-SURFACE ELEVATIONS-BASE TEST
WAVES FROM WEST REPRODUCING STORM OF 28 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

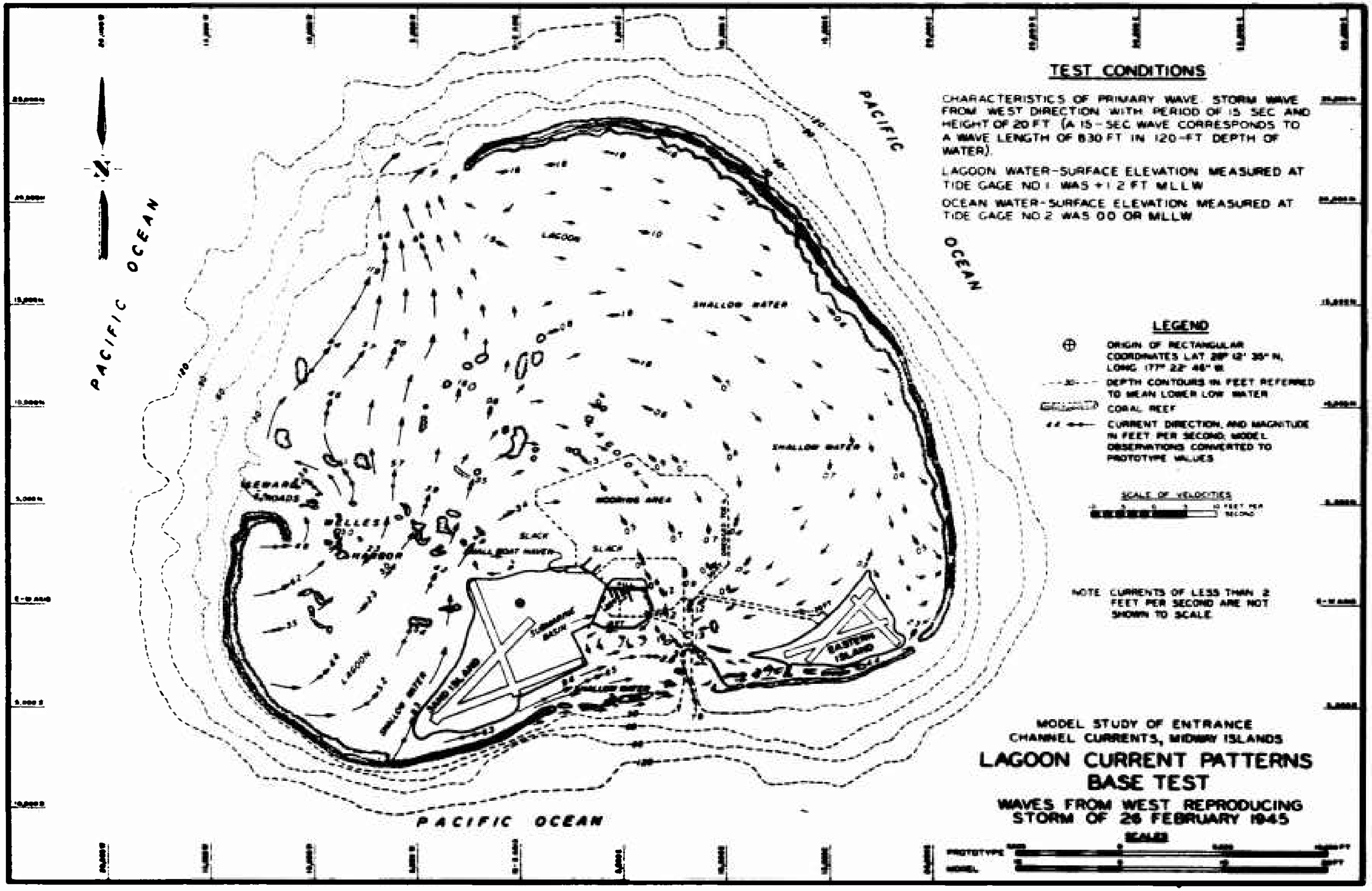
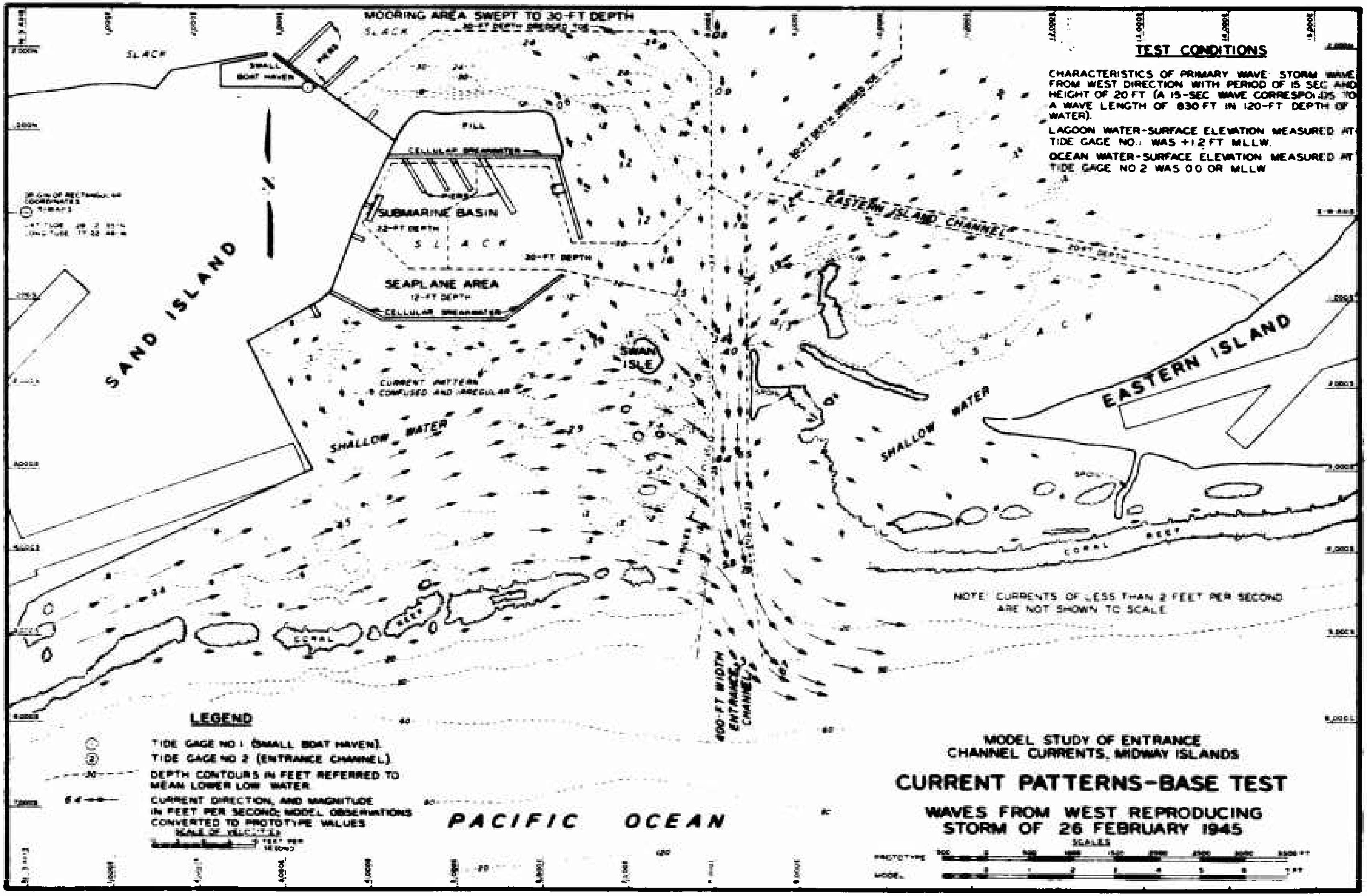

TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
LEGEND
ORIGIN OF RECTANGULAR COORDINATES LAT 28° 12' 35" N, LONG 177° 22' 46" W
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CORAL REEF
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
PACIFIC OCEAN
PACIFIC OCEAN
PACIFIC OCEAN
LAGOON
SHALLOW WATER
MOORING AREA
SLACK
SMALL BOAT HAVEN
WELLES HARBOR
LEEWARD ROADS
SAND ISLAND
EASTERN ISLAND
SUBMARINE BASIN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
LAGOON CURRENT PATTERNS
BASE TEST
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

PLATE 9


MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO. 1 WAS +1.2 FT MLLW.
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
SMALL BOAT HAVEN
PIERS
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
S L A C K
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SWAN ISLE
CURRENT PATTERN CONFUSED AND IRREGULAR
SHALLOW WATER
EASTERN ISLAND CHANNEL
S L A C K
EASTERN ISLAND
SHALLOW WATER
SPOIL
CORAL REEF
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
400-FT WIDTH ENTRANCE CHANNEL
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-BASE TEST
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

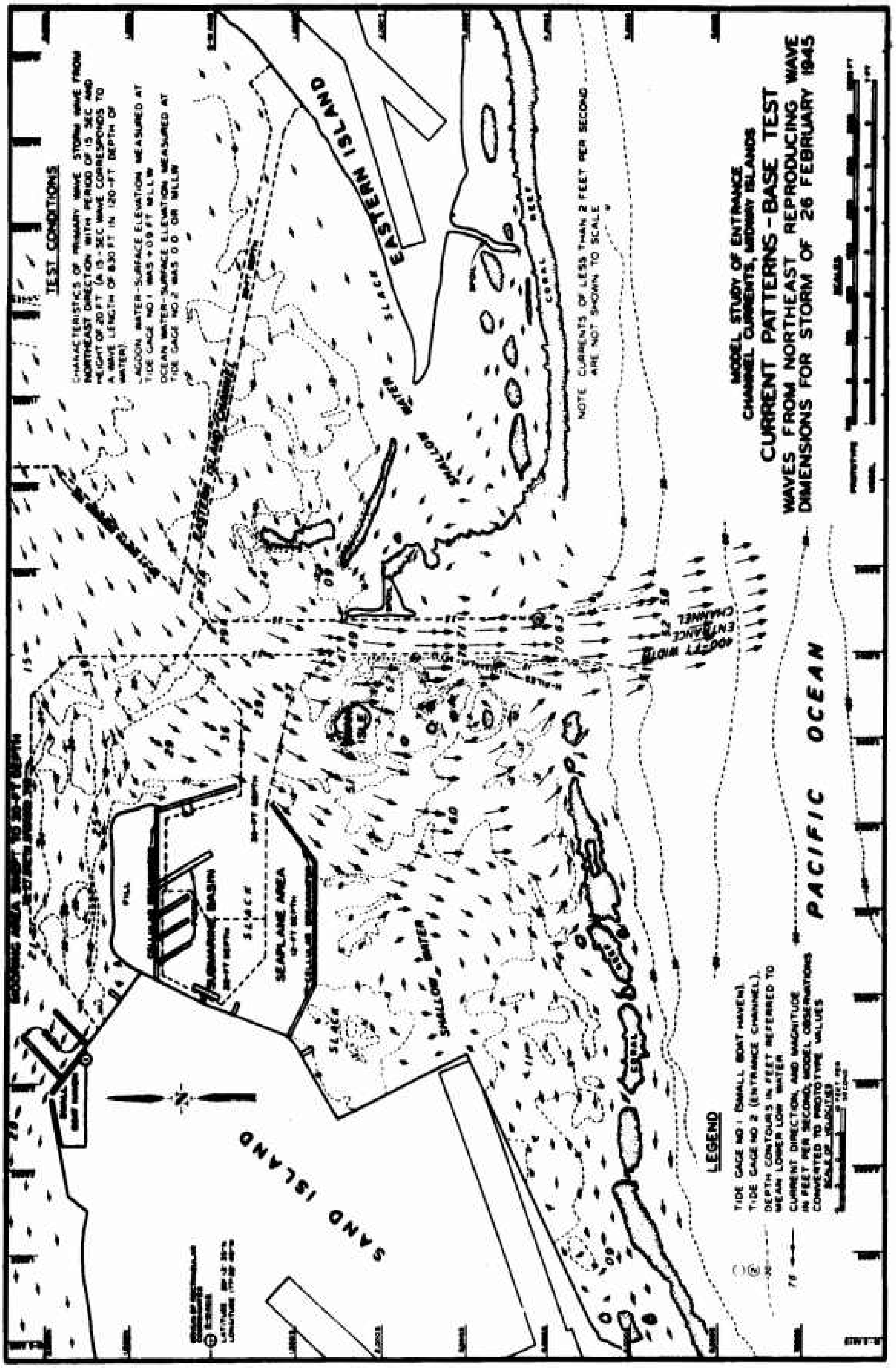
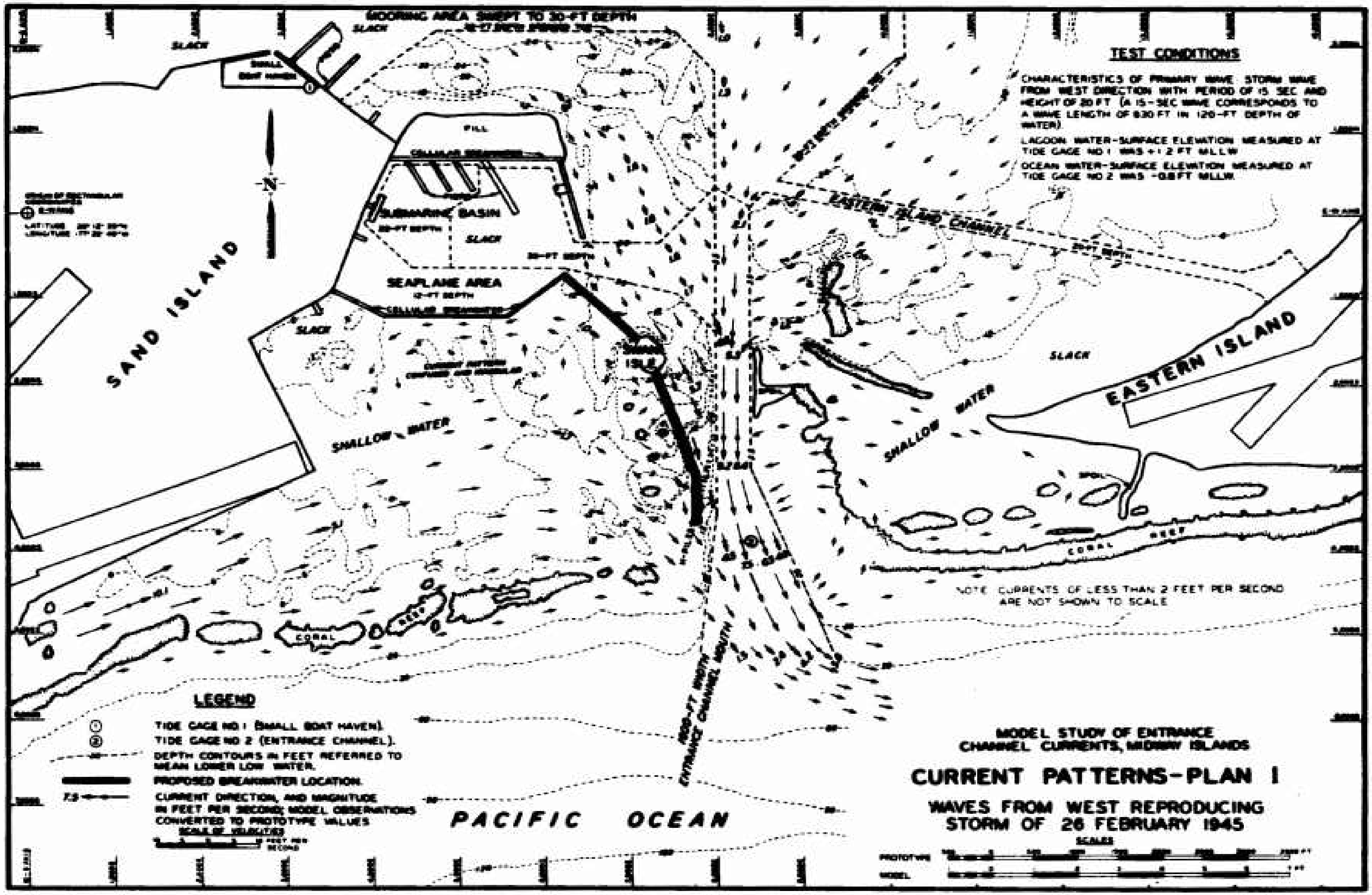

TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM NORTHEAST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +0.9 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
EASTERN ISLAND
SAND ISLAND
PACIFIC OCEAN
SEAPLANE AREA
SUBMARINE BASIN
FILL
SLACK
SHALLOW WATER
CORAL REEF
400-FT WIDTH ENTRANCE CHANNEL
NOTE CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-BASE TEST
WAVES FROM NORTHEAST REPRODUCING WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1945
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES

PLATE 11


MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
SMALL BOAT HAVEN
FILL
SUBMARINE BASIN
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
SAND ISLAND
SHALLOW WATER
CORAL
REEF
EASTERN ISLAND CHANNEL
EASTERN ISLAND
SPOIL
CORAL REEF
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
1600-FT WIDTH ENTRANCE CHANNEL MOUTH
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.8 FT MLLW
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 1
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

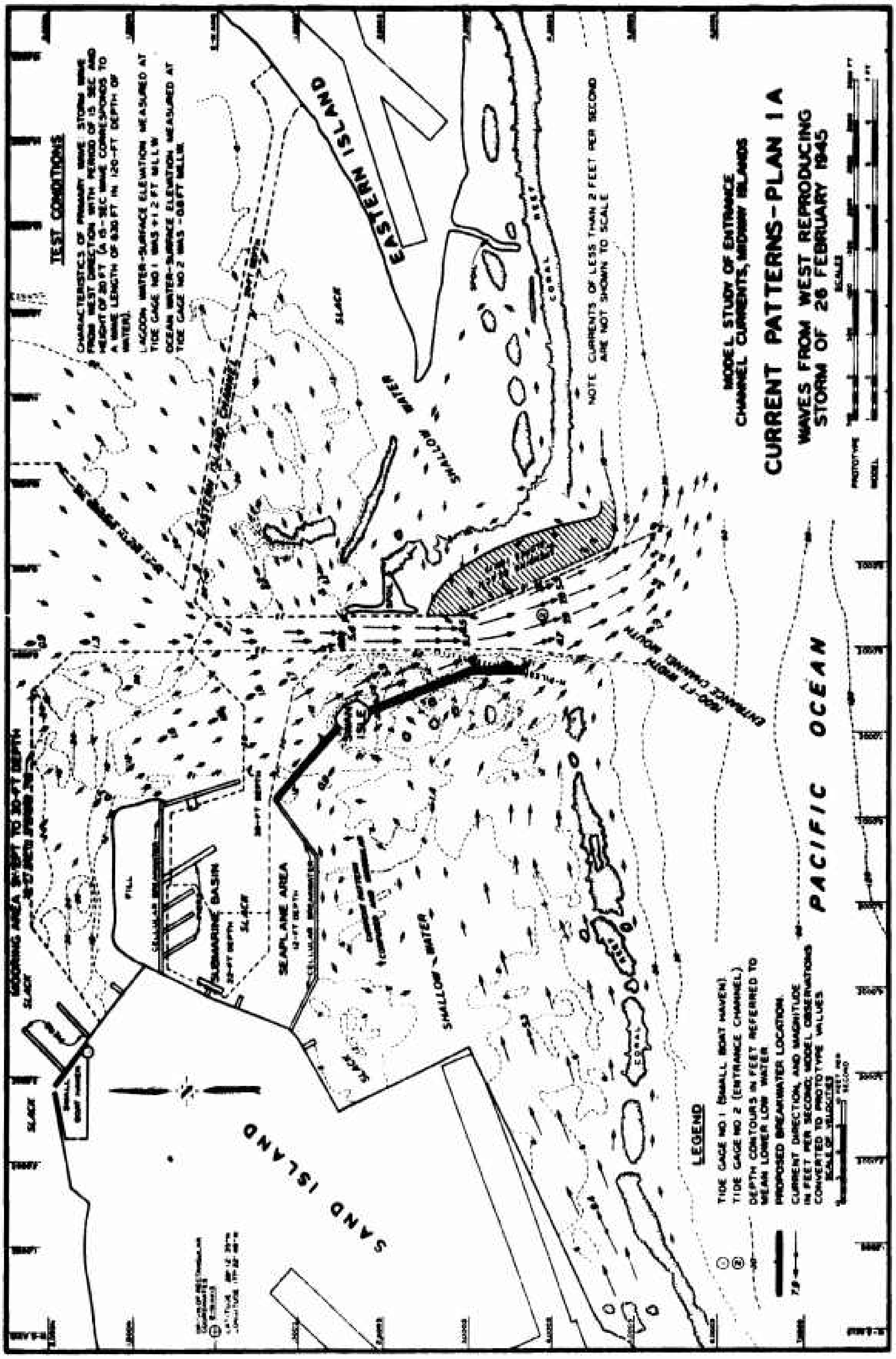
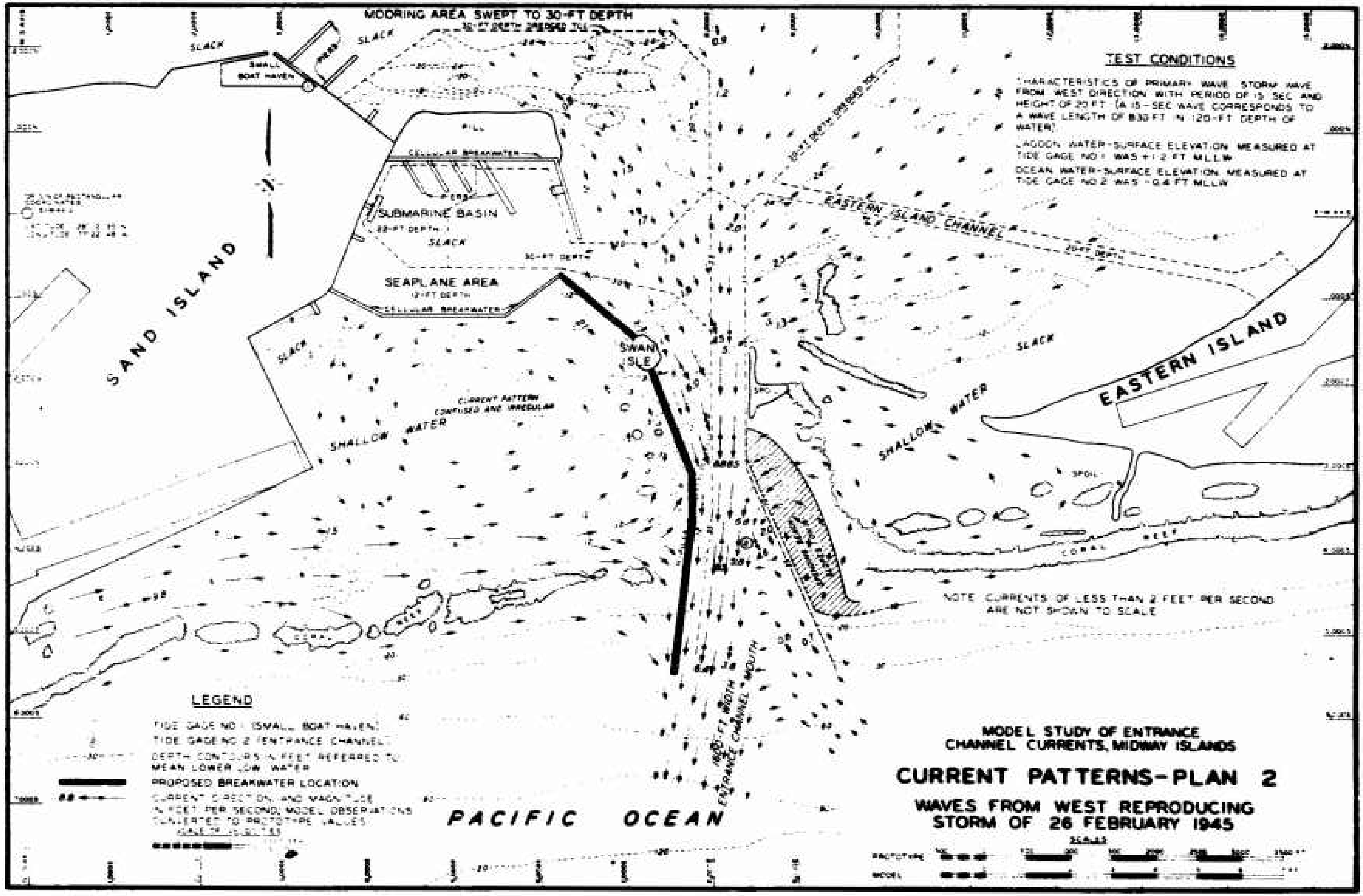
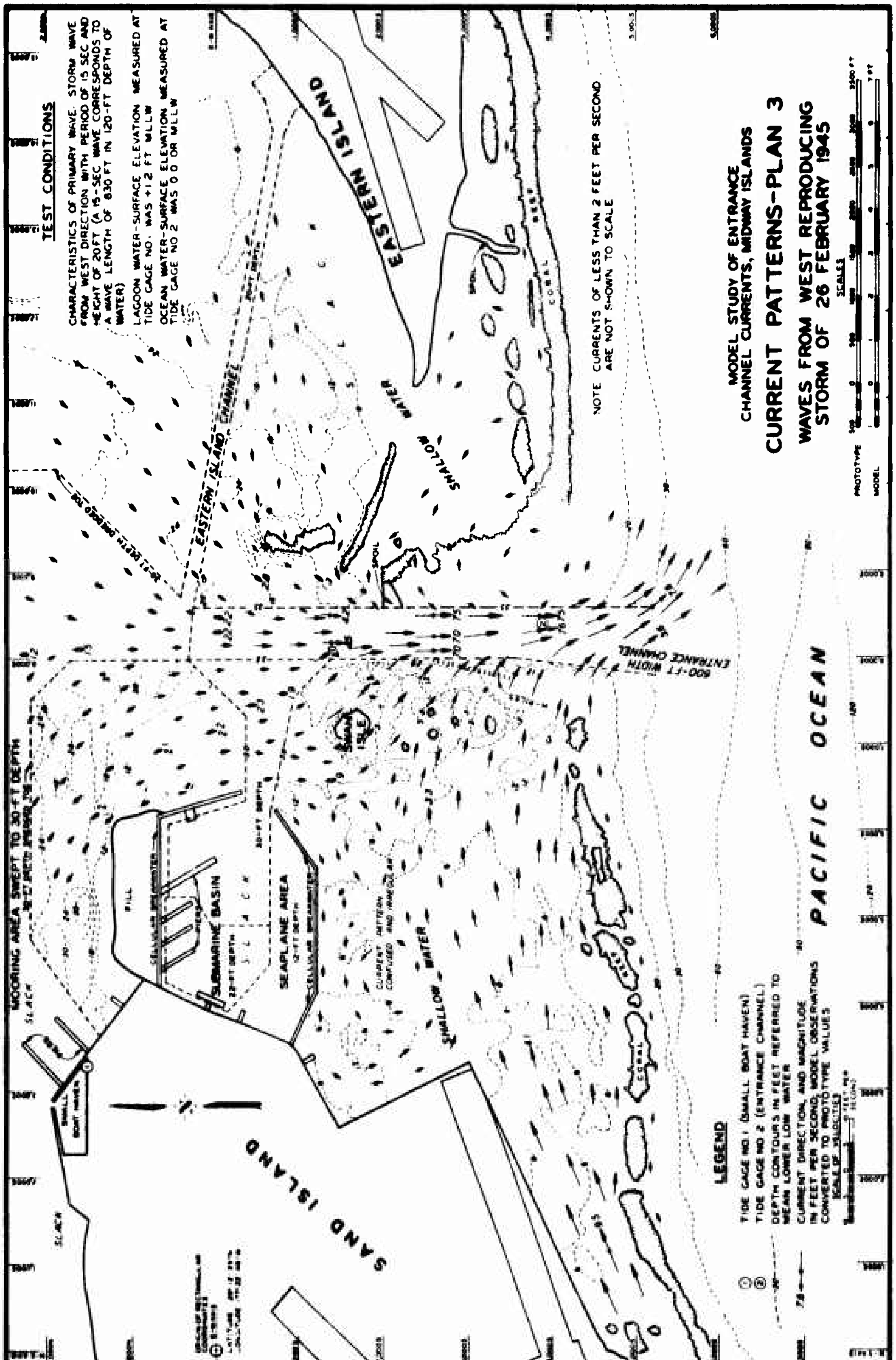
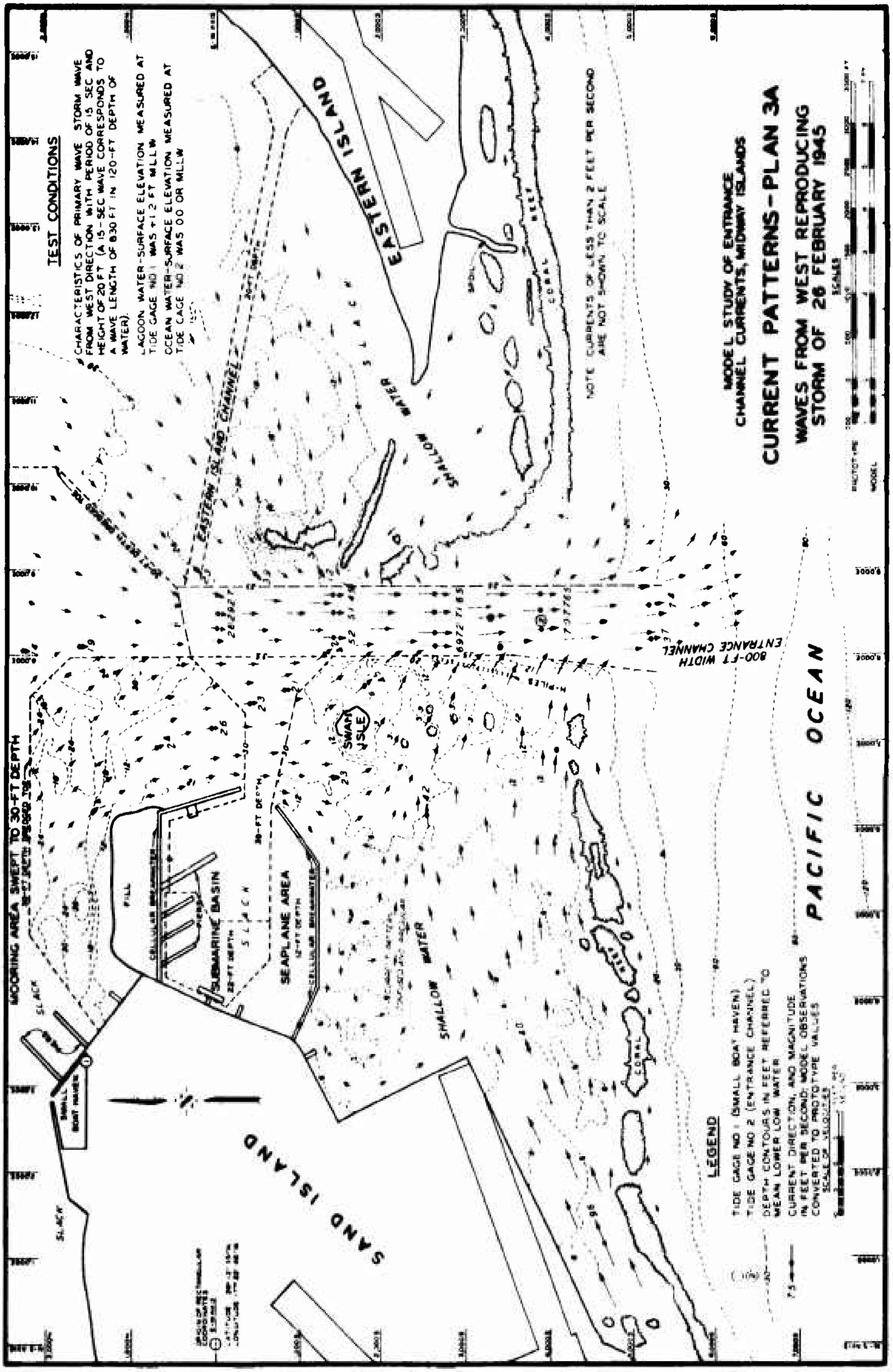
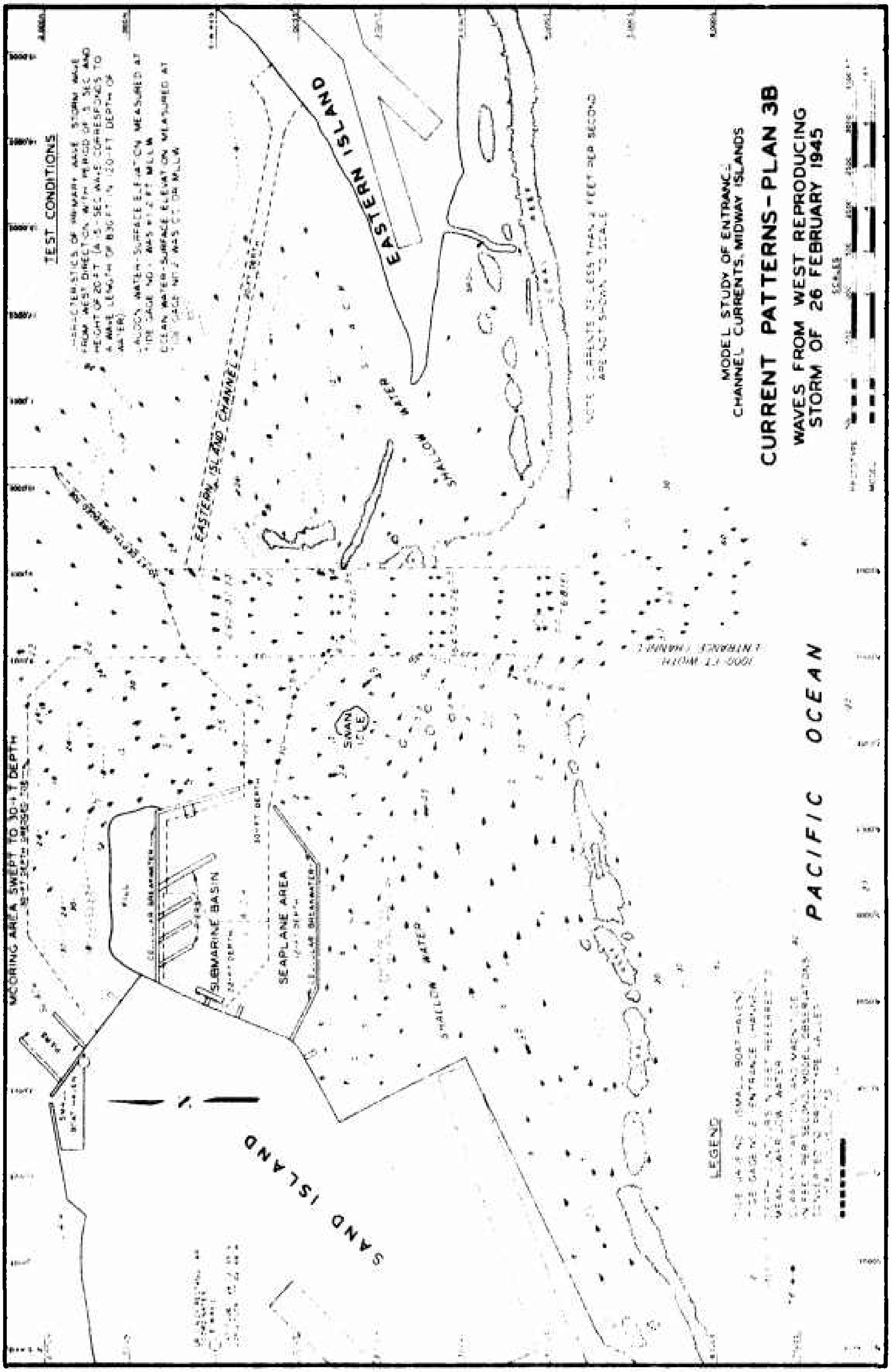

MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SHALLOW WATER
SAND ISLE
SPOIL
EASTERN ISLAND CHANNEL
EASTERN ISLAND
SHALLOW WATER
CORAL REEF
PACIFIC OCEAN
1500-FT WIDTH ENTRANCE CHANNEL MOUTH
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.8 FT MLLW
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 1 A
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

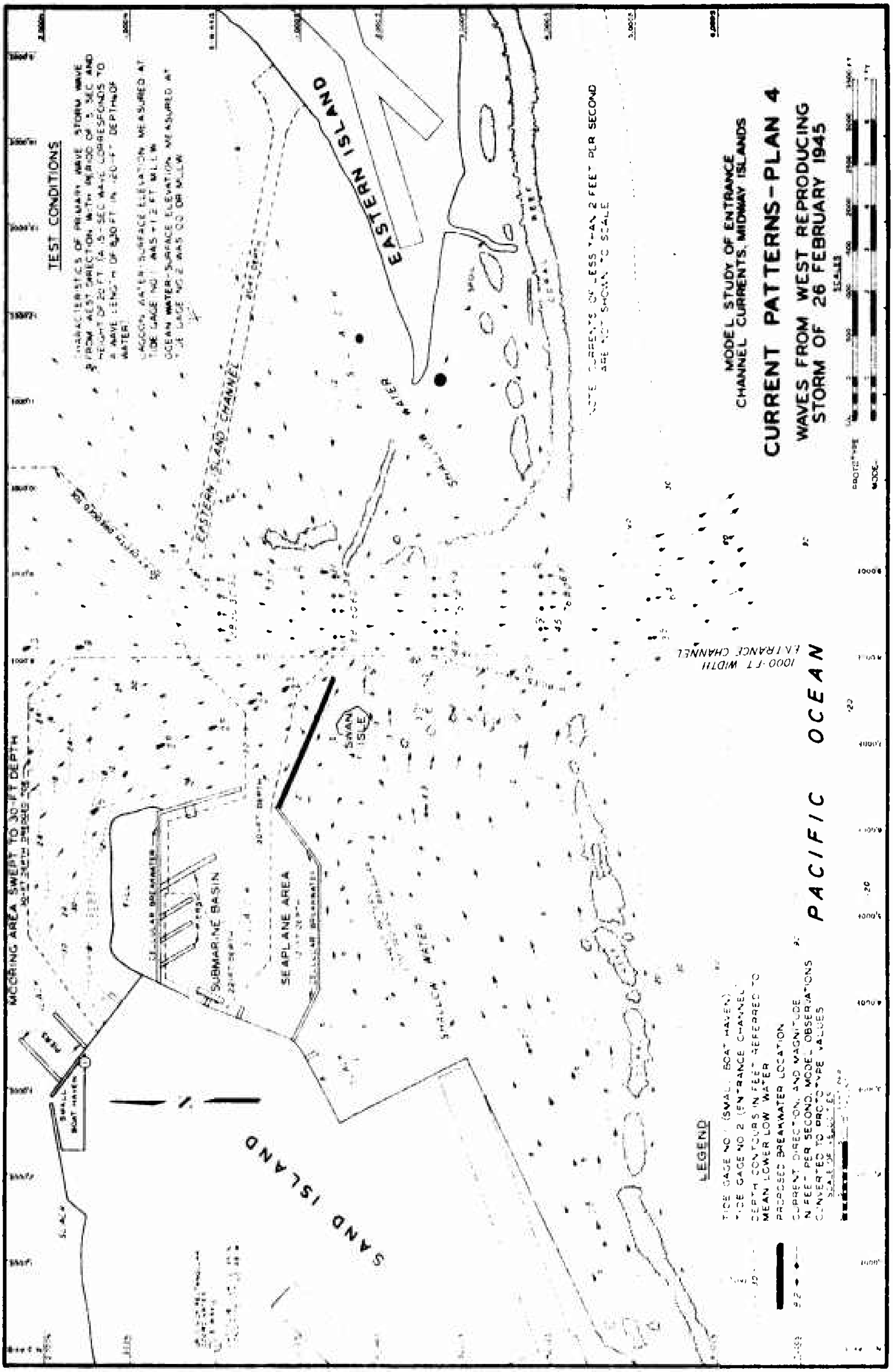
PLATE 13


MOORING AREA SWEPT TO 30-FT DEPTH
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.4 FT MLLW
SLACK
SMALL BOAT HAVEN
PIERS
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
SLACK
SEAPLANE AREA
CELLULAR BREAKWATER
SAND ISLAND
EASTERN ISLAND CHANNEL
EASTERN ISLAND
SWAN ISLE
CURRENT PATTERN CONFUSED AND IRREGULAR
SHALLOW WATER
SPOIL
CORAL REEF
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
1800-FT WIDTH ENTRANCE CHANNEL MOUTH
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 2
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE. STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO. 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
NOTE CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 3
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL
EASTERN ISLAND
EASTERN ISLAND CHANNEL
SHALLOW WATER
SPOIL
CORAL REEF
600-FT WIDTH ENTRANCE CHANNEL
PACIFIC OCEAN
MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
FILL
SUBMARINE BASIN
SEAPLANE AREA
SAND ISLAND
SMALL BOAT HAVEN
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND, MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
MOORING AREA SWEPT TO 30-FT DEPTH
SMALL BOAT HAVEN
SLACK
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
30-FT DEPTH
SAND ISLAND
SWAN ISLE
SHALLOW WATER
EASTERN ISLAND CHANNEL
EASTERN ISLAND
SPOIL
CORAL REEF
H-PILES
800-FT WIDTH ENTRANCE CHANNEL
NOTE CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
PACIFIC OCEAN
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 3A
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


TEST CONDITIONS
EASTERN ISLAND
EASTERN ISLAND CHANNEL
MOORING AREA SWEPT TO 30-FT DEPTH
SUBMARINE BASIN
SEAPLANE AREA
SHALLOW WATER
SHALLOW WATER
1000-FT WIDTH ENTRANCE CHANNEL
SAND ISLAND
PACIFIC OCEAN
LEGEND
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS–PLAN 3B
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES


MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 4
WAVES FROM WEST REPRODUCING
STORM OF 26 FEBRUARY 1945
TEST CONDITIONS
LEGEND
EASTERN ISLAND
EASTERN ISLAND CHANNEL
SAND ISLAND
PACIFIC OCEAN
1000-FT WIDTH
ENTRANCE CHANNEL
MOORING AREA SWEPT TO 30-FT DEPTH
SUBMARINE BASIN
SEAPLANE AREA
SMALL BOAT HAVEN
SHALLOW WATER
REEF

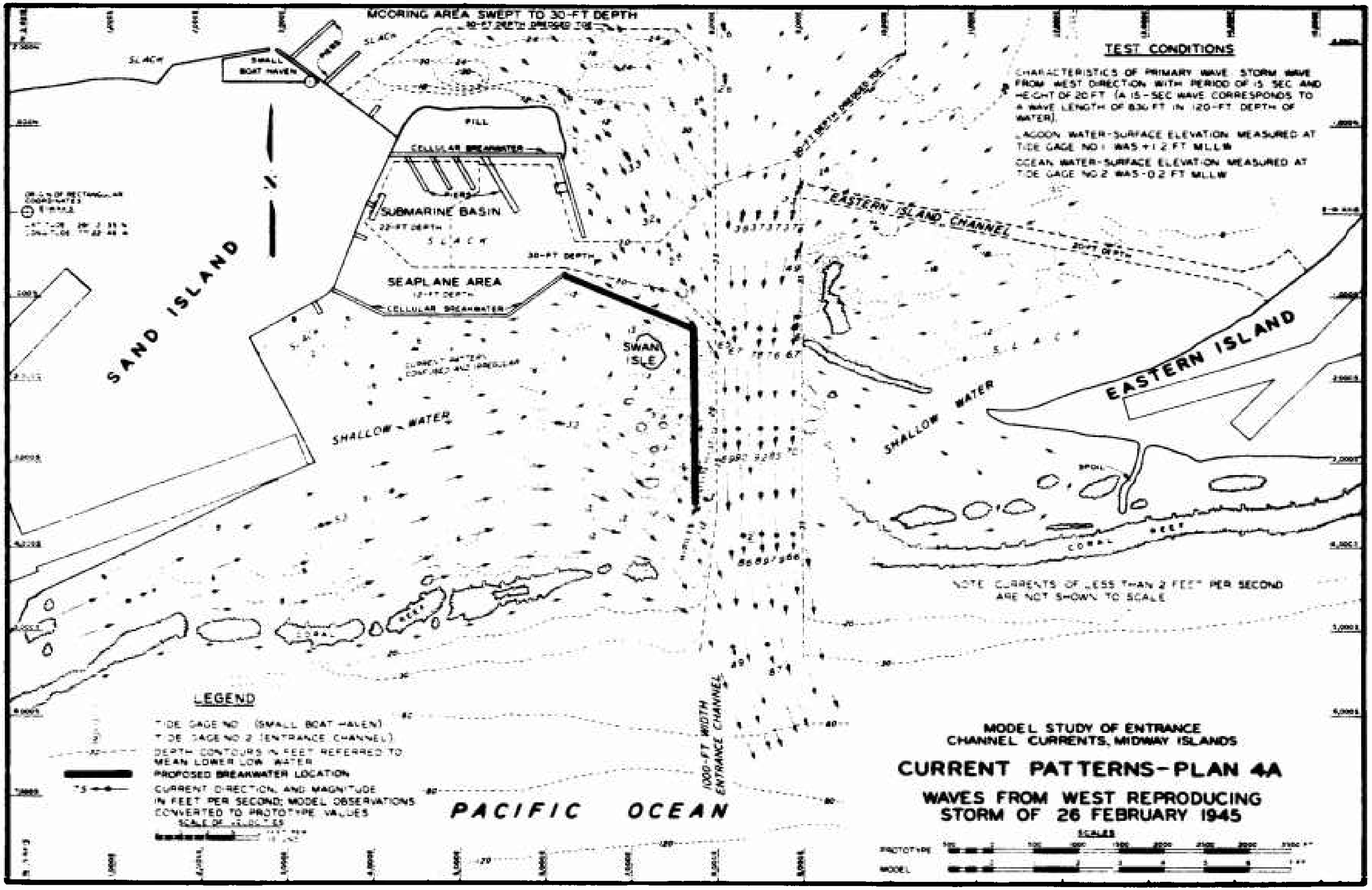
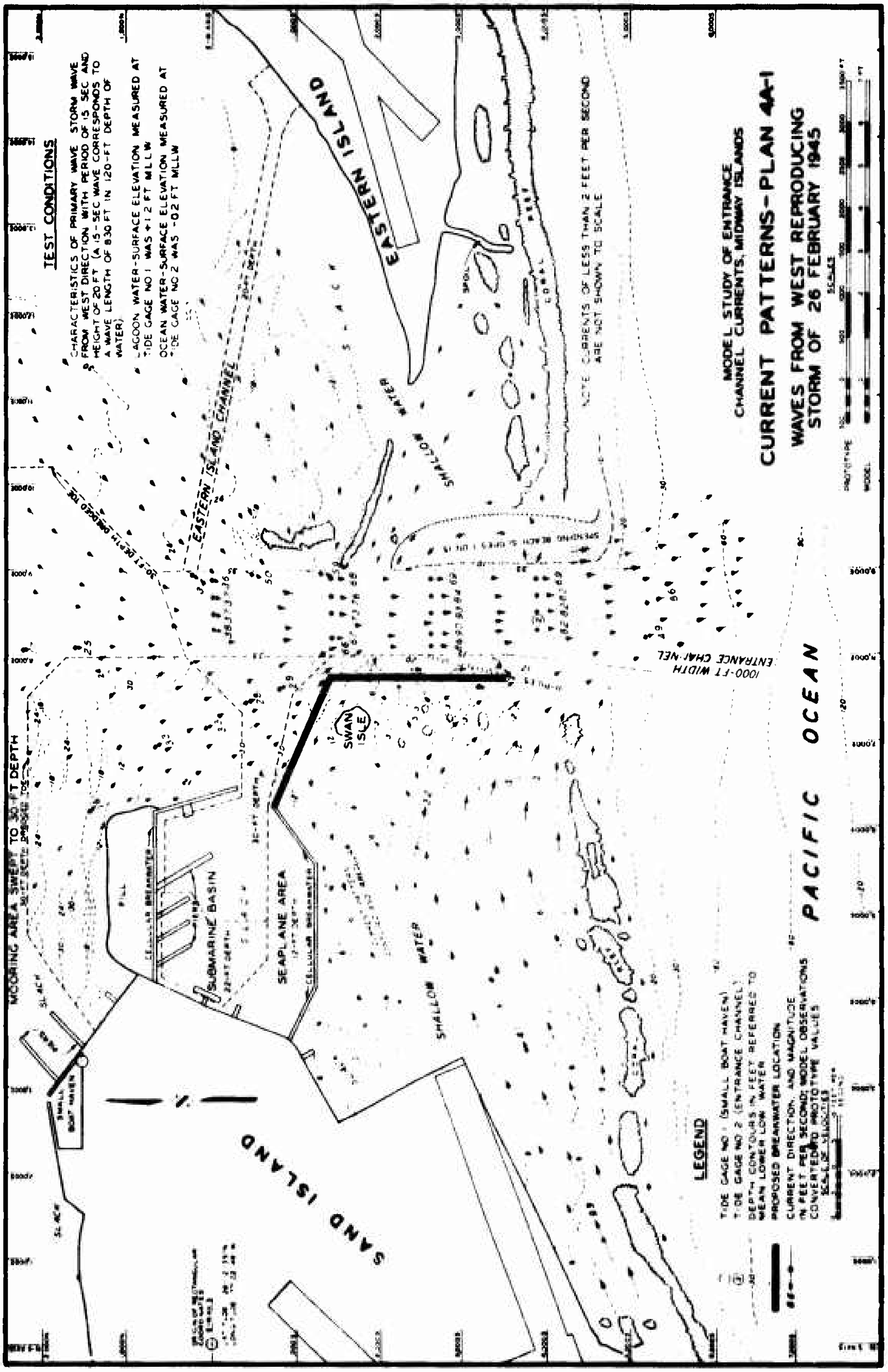

MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
SMALL BOAT HAVEN
PIERS
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SWAN ISLE
SHALLOW WATER
CORAL
REEF
EASTERN ISLAND CHANNEL
20-FT DEPTH
EASTERN ISLAND
SHALLOW WATER
SLACK
SPOIL
CORAL REEF
1000-FT WIDTH ENTRANCE CHANNEL
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.2 FT MLLW
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 4A
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

PLATE 19


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.2 FT MLLW
EASTERN ISLAND
EASTERN ISLAND CHANNEL
MOORING AREA SWEPT TO 30-FT DEPTH
SUBMARINE BASIN
SEAPLANE AREA
SHALLOW WATER
SWAN ISLE
1000-FT WIDTH ENTRANCE CHANNEL
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
SAND ISLAND
PACIFIC OCEAN
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 4A-1
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945

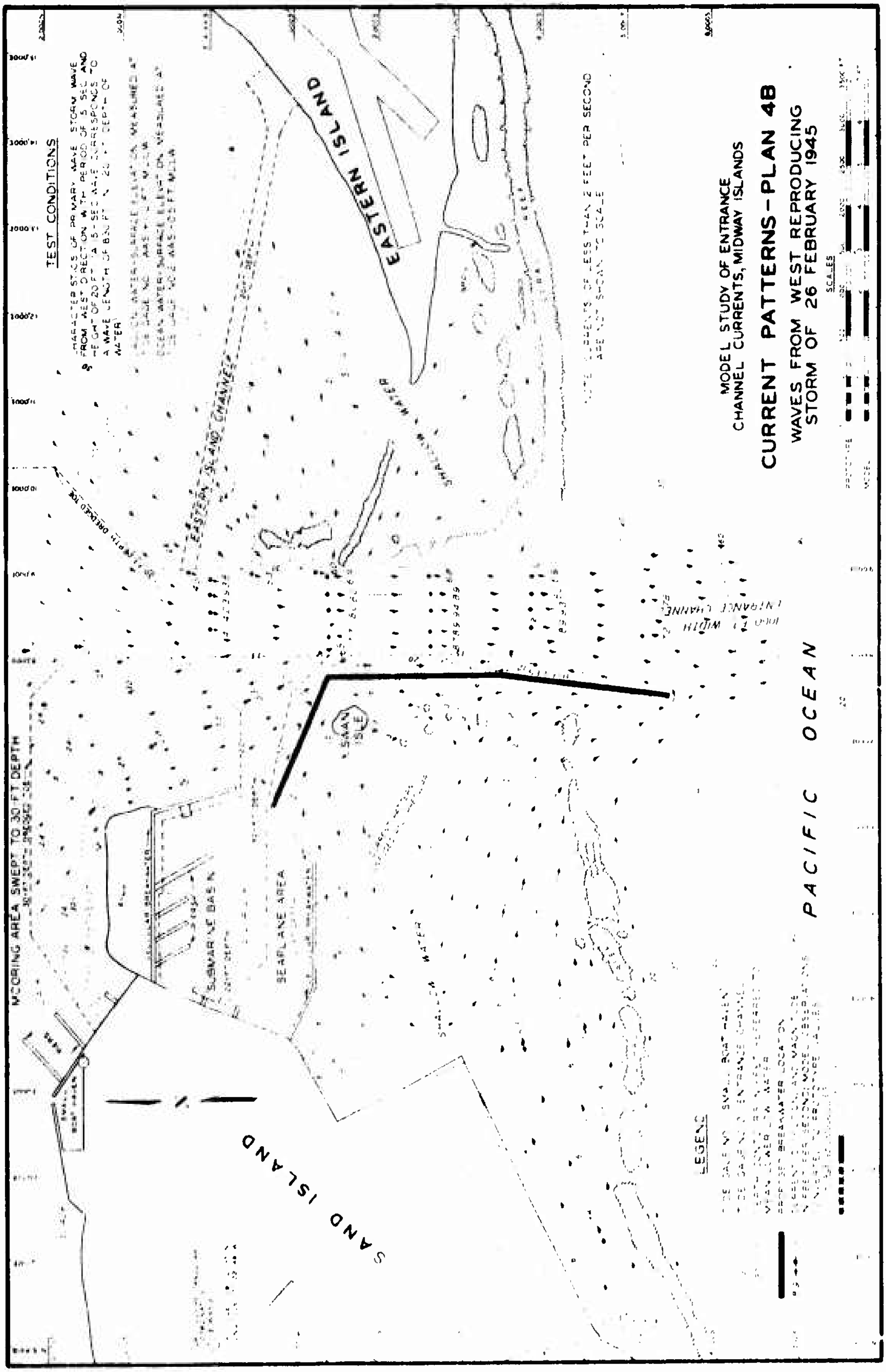
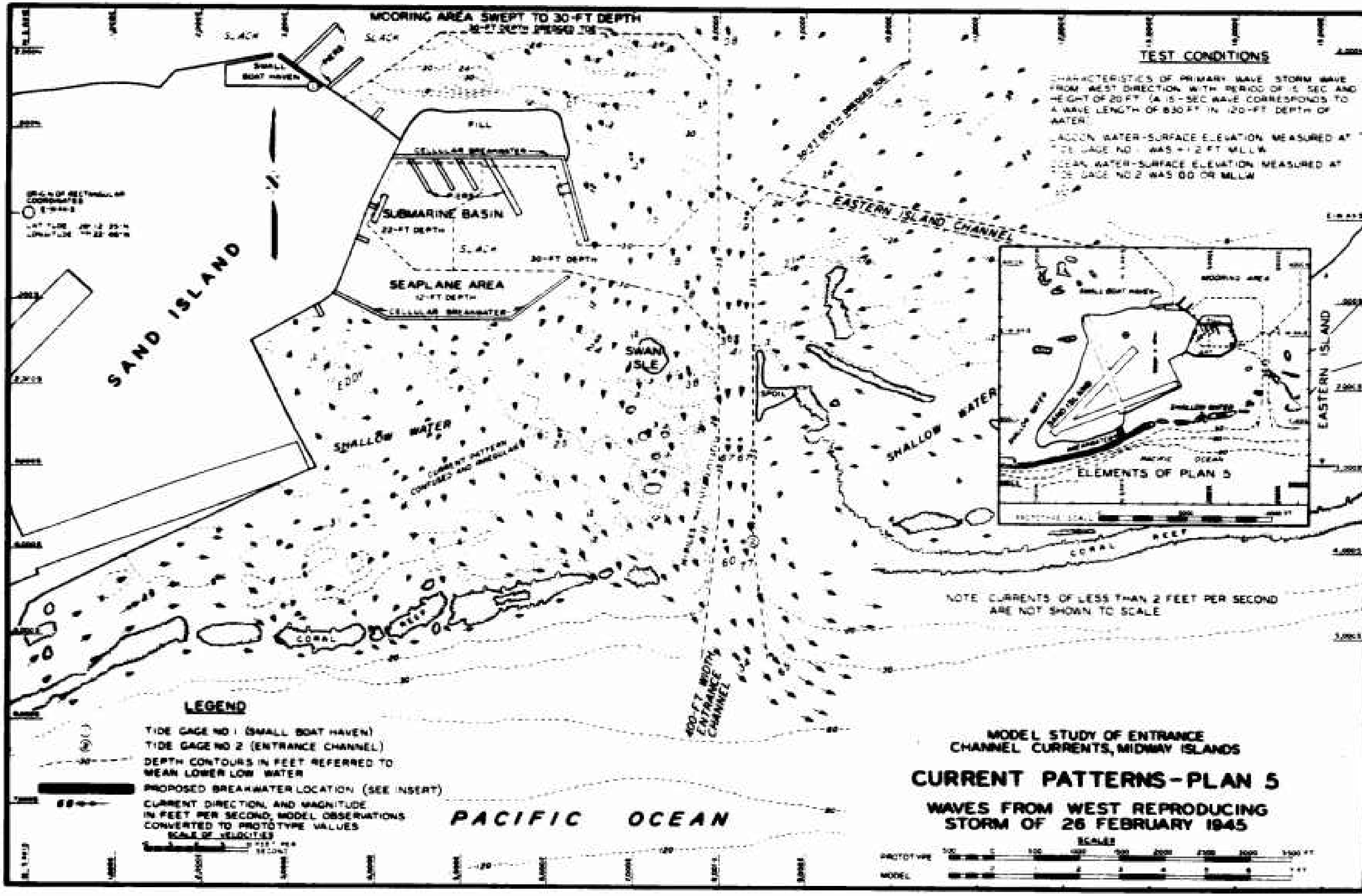
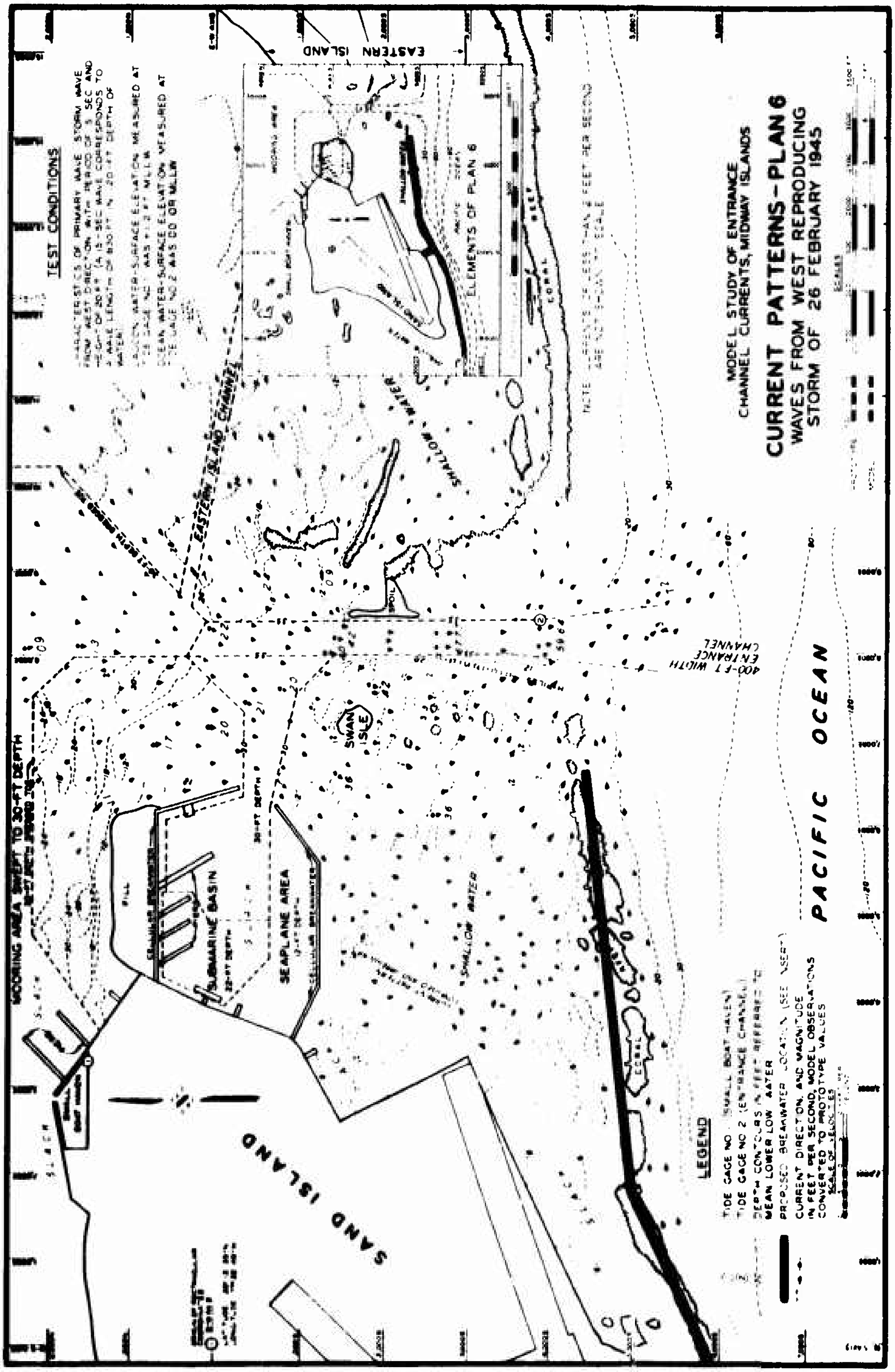
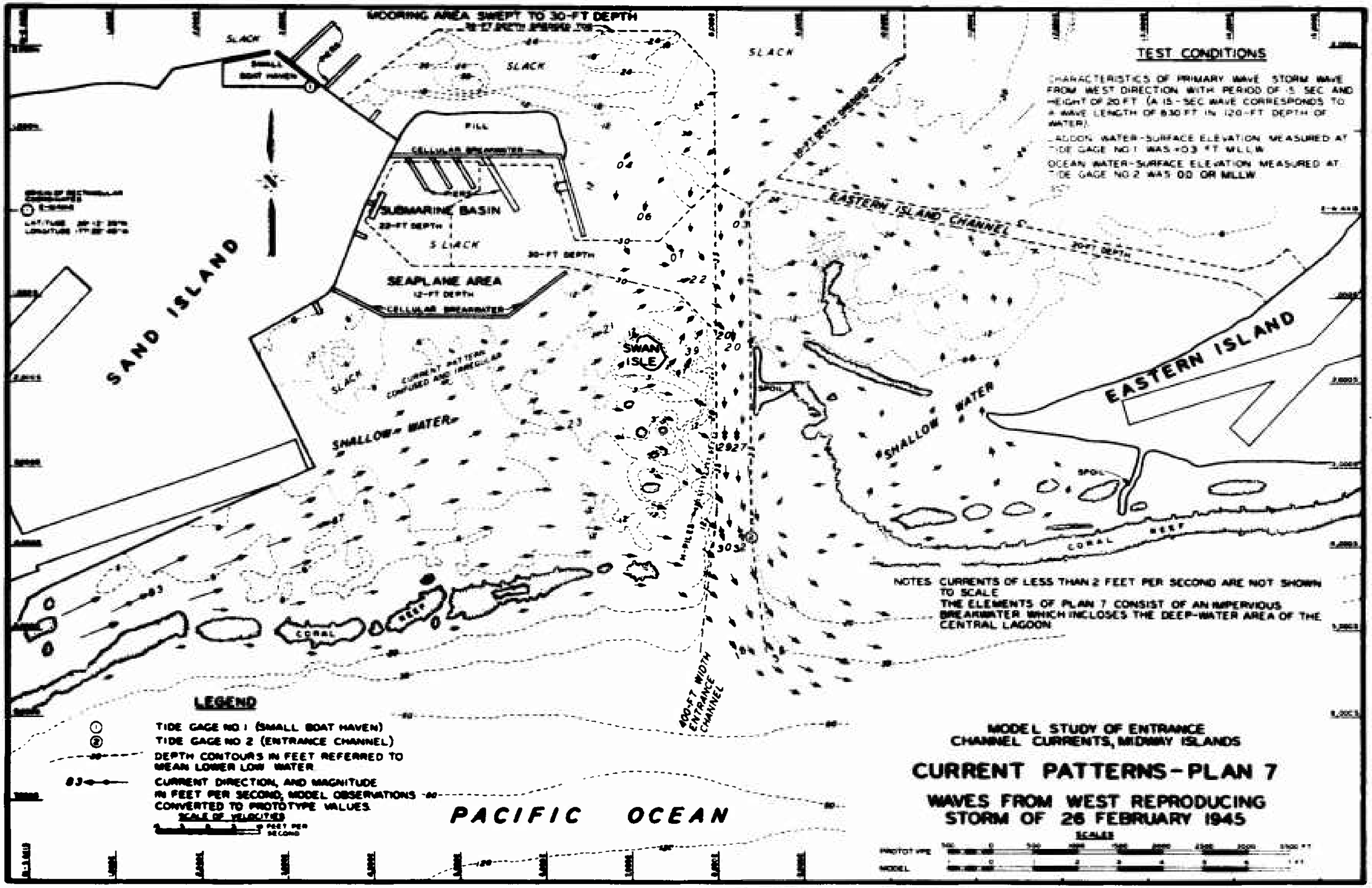

TEST CONDITIONS
EASTERN ISLAND
EASTERN ISLAND CHANNEL
ENTRANCE CHANNEL
1000 FT WIDTH
MOORING AREA SWEPT TO 30 FT DEPTH
SUBMARINE BASIN
SEAPLANE AREA
SAND ISLAND
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS - PLAN 4B
WAVES FROM WEST REPRODUCING
STORM OF 26 FEBRUARY 1945
SCALES
LEGEND

PLATE 21


MOORING AREA SWEPT TO 30-FT DEPTH
30-FT DEPTH DREDGED TOE
SLACK
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
EDDY
SHALLOW WATER
CURRENT PATTERN CONFUSED AND IRREGULAR
SWAN ISLE
SPOIL
SHALLOW WATER
EASTERN ISLAND CHANNEL
30-FT DEPTH DREDGED TOE
400-FT WIDTH ENTRANCE CHANNEL
EASTERN ISLAND
CORAL REEF
CORAL
REEF
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.2 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
ELEMENTS OF PLAN 5
NOTE CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION (SEE INSERT)
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND, MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS - PLAN 5
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS–PLAN 6
WAVES FROM WEST REPRODUCING
STORM OF 26 FEBRUARY 1945
TEST CONDITIONS
LEGEND
TIDE GAGE NO. 1 (SMALL BOAT HAVEN)
TIDE GAGE NO. 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION (SEE INSET)
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND, MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
ELEMENTS OF PLAN 6
MOORING AREA SWEPT TO 30-FT DEPTH
SUBMARINE BASIN
SEAPLANE AREA
SWAN ISLE
EASTERN ISLAND CHANNEL
SHALLOW WATER
400-FT WIDTH ENTRANCE CHANNEL
SPOIL
CORAL
REEF
SAND ISLAND
EASTERN ISLAND
PACIFIC OCEAN



MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
23-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
N
CURRENT PATTERN CONFUSED AND IRREGULAR
SLACK
SHALLOW WATER
SWAN ISLE
EASTERN ISLAND CHANNEL
20-FT DEPTH
EASTERN ISLAND
SHALLOW WATER
SPOIL
CORAL REEF
CORAL
REEF
400-FT WIDTH ENTRANCE CHANNEL
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE. STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +0.3 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
NOTES: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
THE ELEMENTS OF PLAN 7 CONSIST OF AN IMPERVIOUS BREAKWATER WHICH INCLOSES THE DEEP-WATER AREA OF THE CENTRAL LAGOON
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND, MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 7
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


PLATE 24

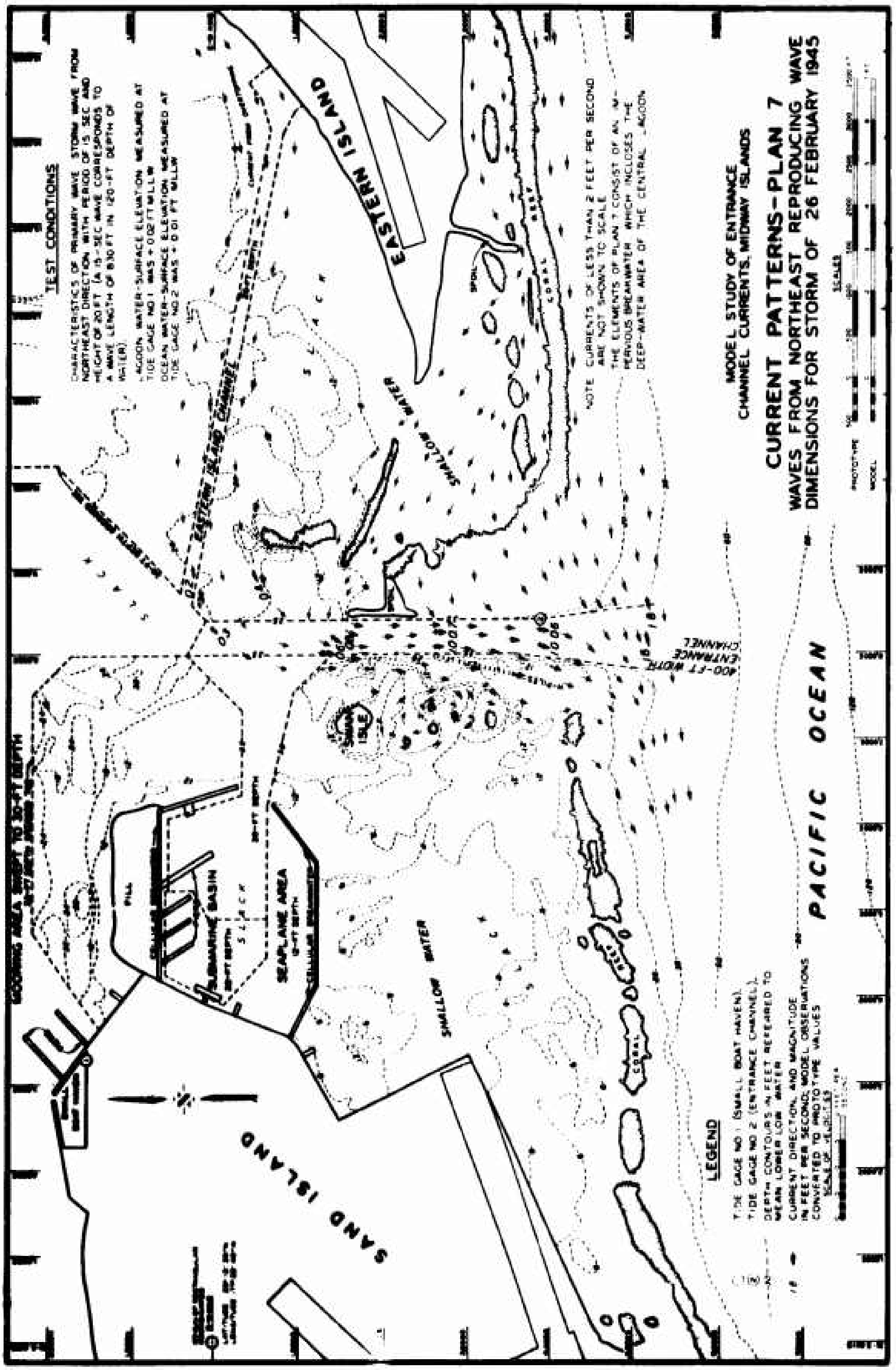
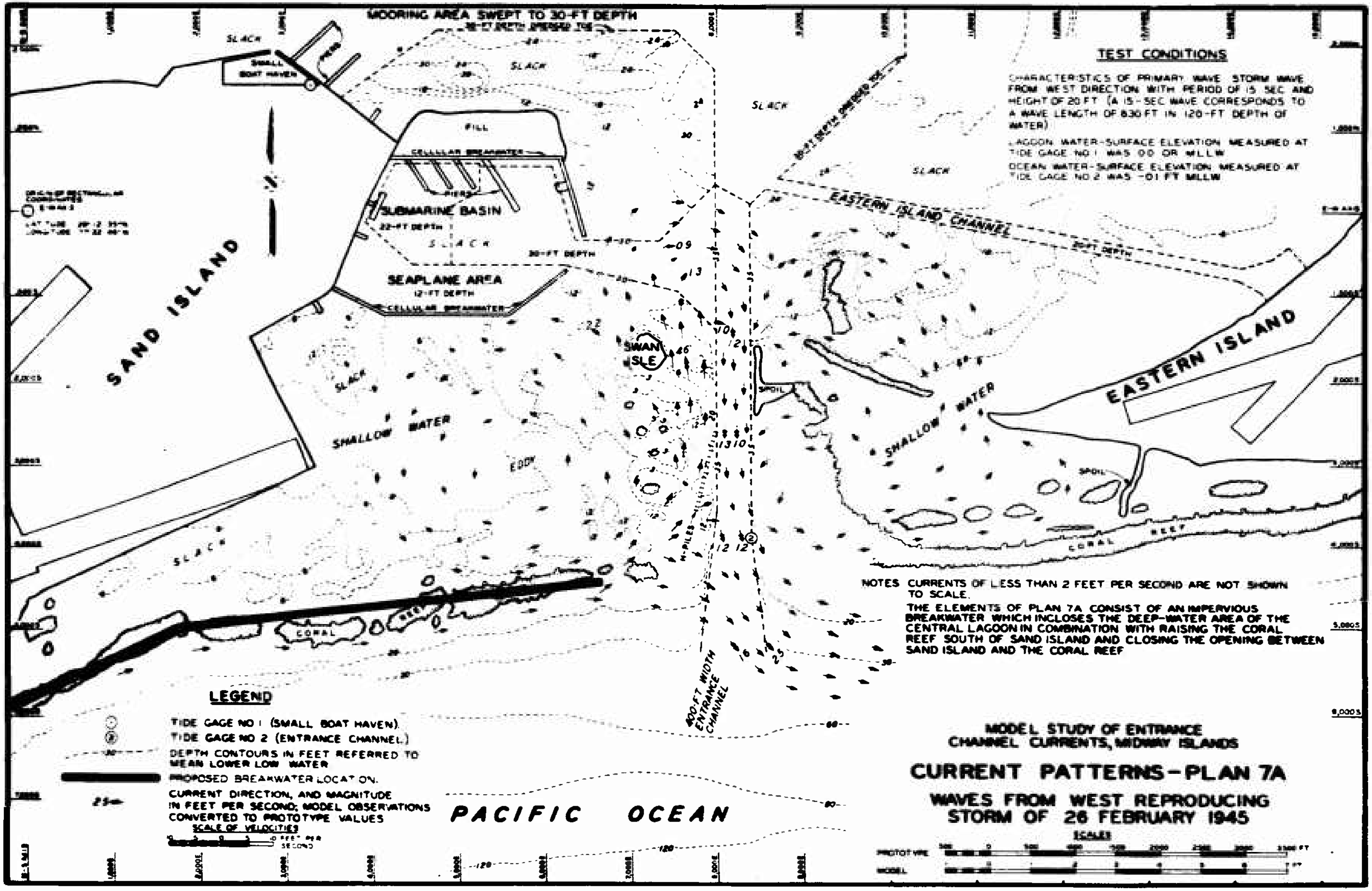
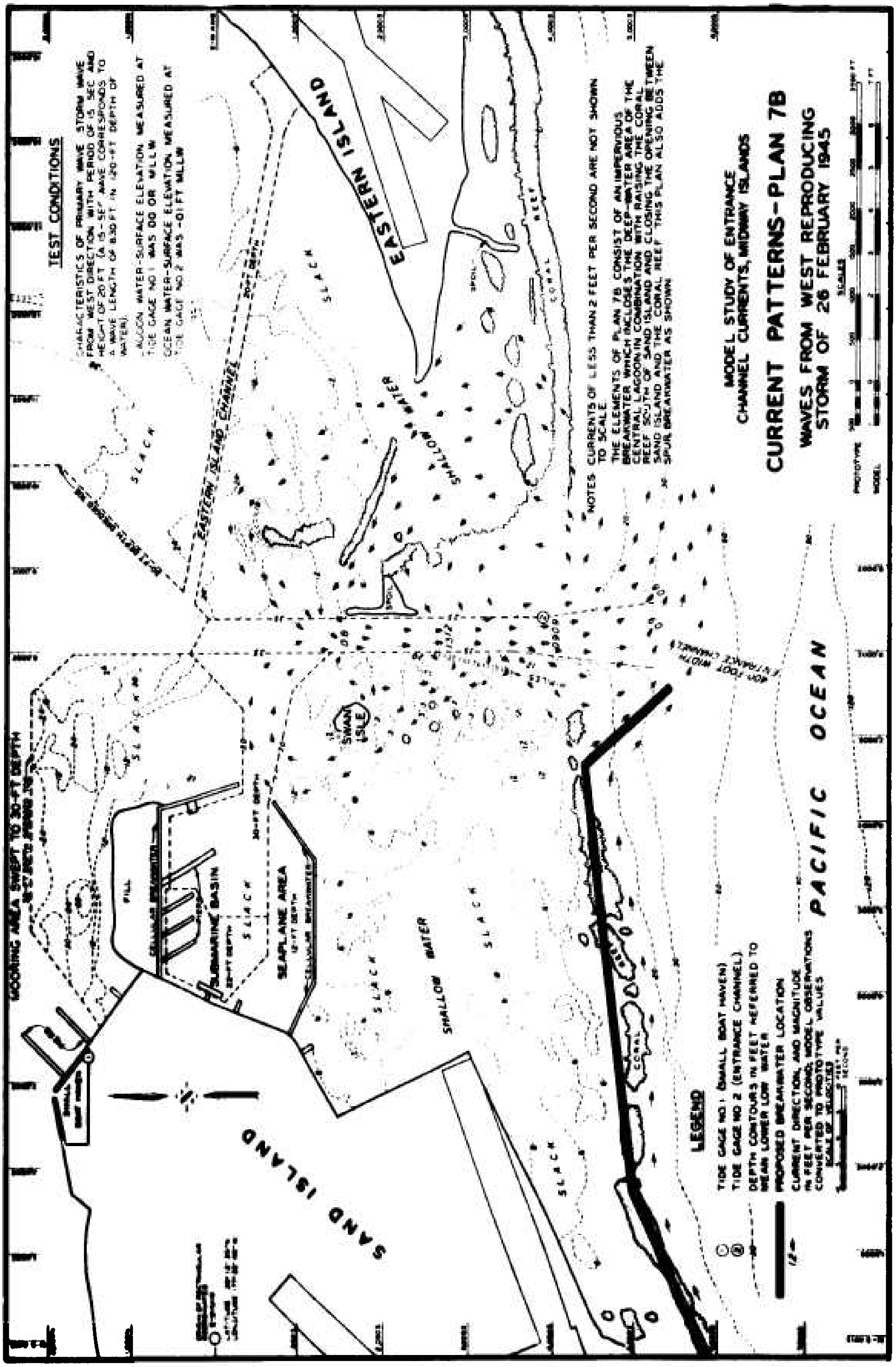
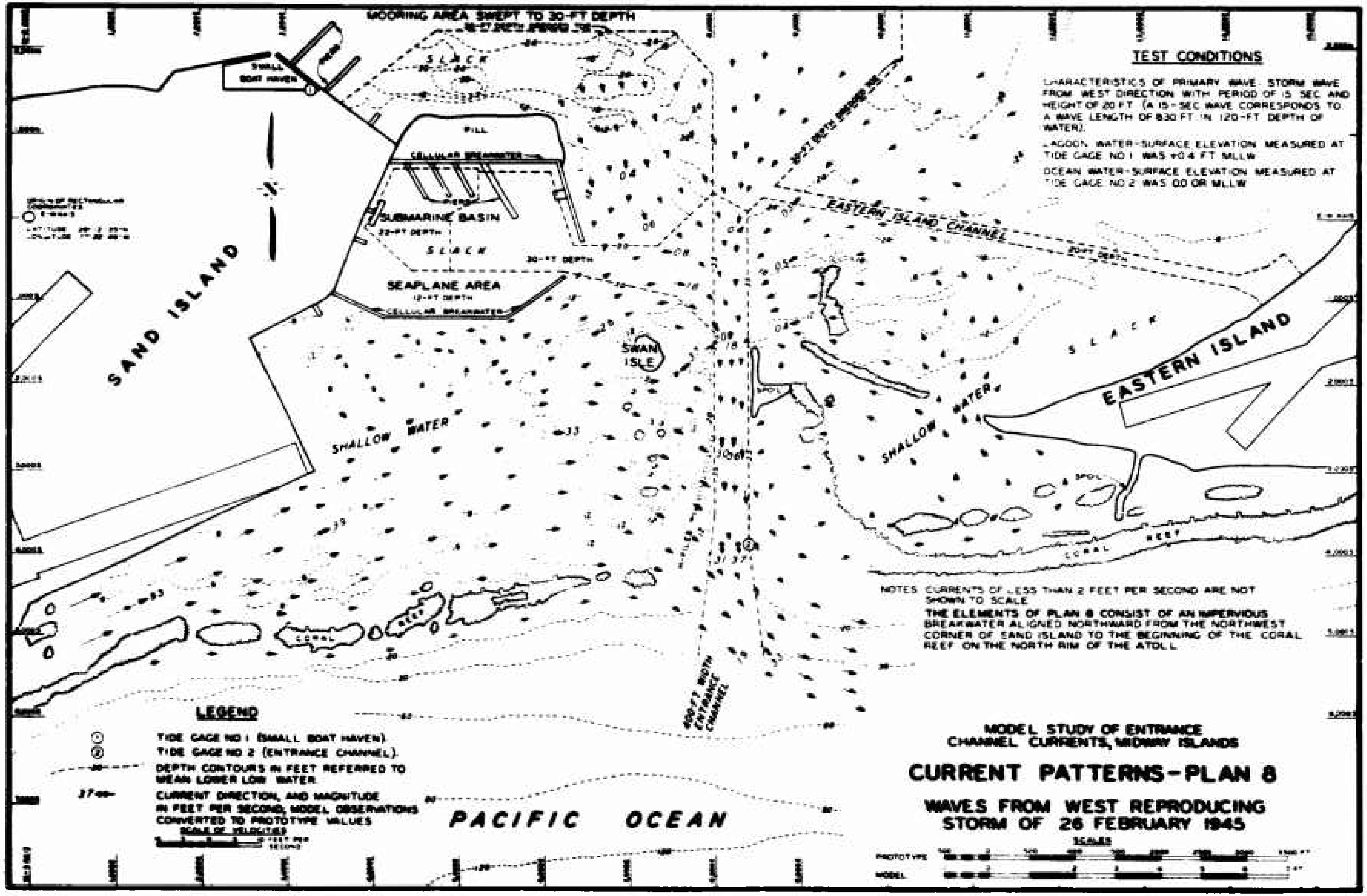
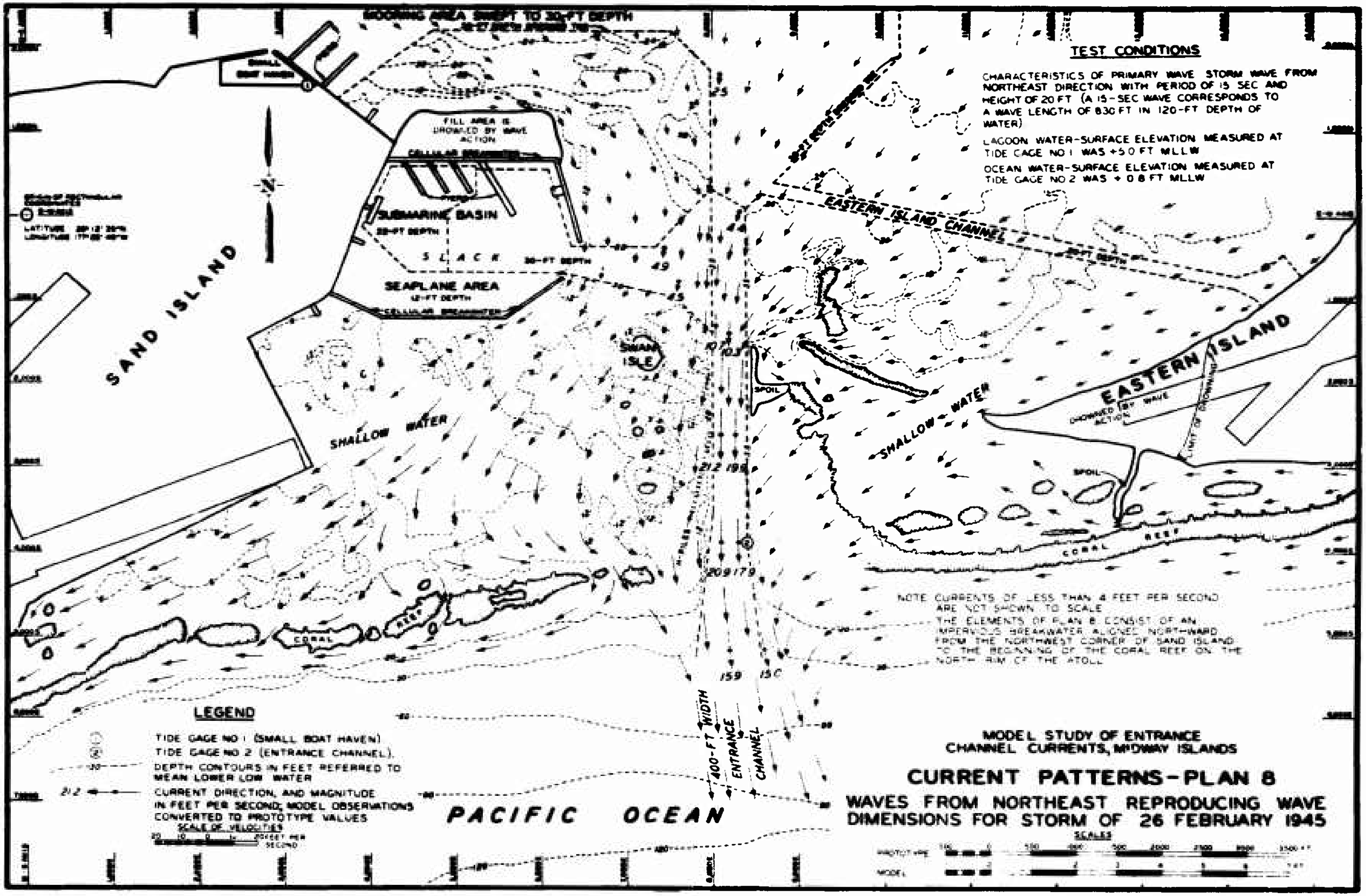

TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM NORTHEAST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
EASTERN ISLAND
SHALLOW WATER
EASTERN ISLAND CHANNEL
NOTE CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
400-FT WIDTH ENTRANCE CHANNEL
SAND ISLAND
SUBMARINE BASIN
SEAPLANE AREA
FILL
SHALLOW WATER
PACIFIC OCEAN
LEGEND
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS–PLAN 7
WAVES FROM NORTHEAST REPRODUCING WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL

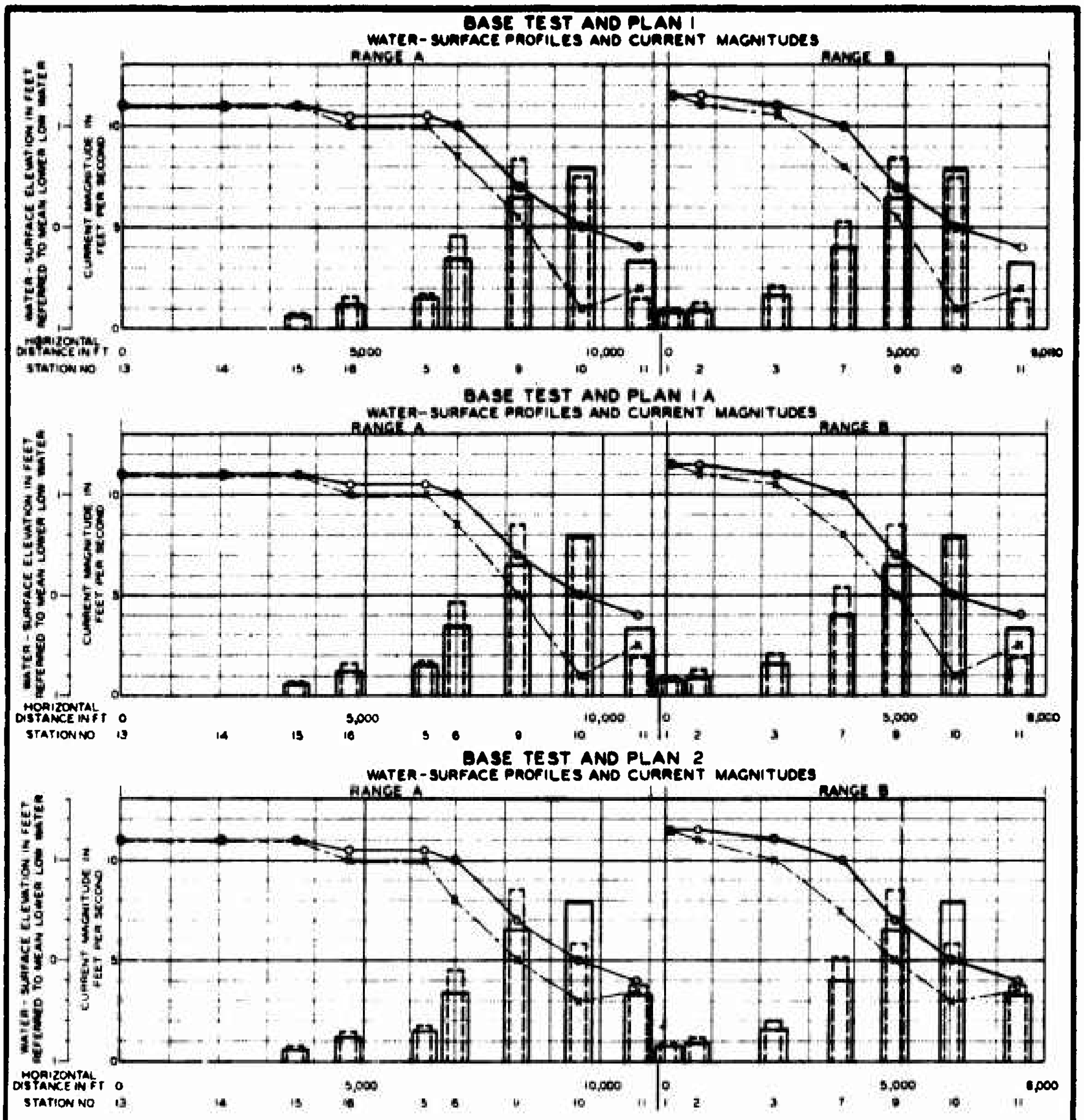
PLATE 25

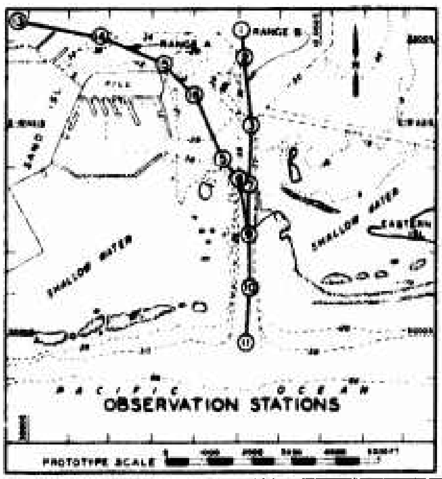

MOORING AREA SWEPT TO 30-FT DEPTH
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS 0.0 OR MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.1 FT MLLW
SLACK
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
PIERS
SUBMARINE BASIN
22-FT DEPTH
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
SAND ISLAND
SWAN ISLE
SPOIL
EASTERN ISLAND CHANNEL
20-FT DEPTH
EASTERN ISLAND
SHALLOW WATER
EDDY
CORAL REEF
H-PILES
400-FT WIDTH ENTRANCE CHANNEL
NOTES CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE.
THE ELEMENTS OF PLAN 7A CONSIST OF AN IMPERVIOUS BREAKWATER WHICH INCLOSES THE DEEP-WATER AREA OF THE CENTRAL LAGOON IN COMBINATION WITH RAISING THE CORAL REEF SOUTH OF SAND ISLAND AND CLOSING THE OPENING BETWEEN SAND ISLAND AND THE CORAL REEF
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
FEET PER SECOND
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 7A
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS 0.0 OR MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS -0.1 FT MLLW
NOTES CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
THE ELEMENTS OF PLAN 7B CONSIST OF AN IMPERVIOUS BREAKWATER WHICH INCLOSES THE DEEP-WATER AREA OF THE CENTRAL LAGOON IN COMBINATION WITH RAISING THE CORAL REEF SOUTH OF SAND ISLAND AND CLOSING THE OPENING BETWEEN SAND ISLAND AND THE CORAL REEF. THIS PLAN ALSO ADDS THE SPUR BREAKWATER AS SHOWN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 7B
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL
EASTERN ISLAND
EASTERN ISLAND CHANNEL
SAND ISLAND
PACIFIC OCEAN
SWAN ISLE
SUBMARINE BASIN
SEAPLANE AREA
FILL
SHALLOW WATER
SLACK
SPOIL
CORAL REEF
400-FOOT WIDTH ENTRANCE CHANNEL
MOORING AREA SWEPT TO 30-FT DEPTH
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
PROPOSED BREAKWATER LOCATION
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND, MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES


MOORING AREA SWEPT TO 30-FT DEPTH
SMALL BOAT HAVEN
SLACK
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
22-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SWAN ISLE
SHALLOW WATER
EASTERN ISLAND CHANNEL
20-FT DEPTH
SLACK
EASTERN ISLAND
SHALLOW WATER
SPOIL
CORAL REEF
400-FT WIDTH ENTRANCE CHANNEL
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER).
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +0.4 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
NOTES: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
THE ELEMENTS OF PLAN 8 CONSIST OF AN IMPERVIOUS BREAKWATER ALIGNED NORTHWARD FROM THE NORTHWEST CORNER OF SAND ISLAND TO THE BEGINNING OF THE CORAL REEF ON THE NORTH RIM OF THE ATOLL
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 8
WAVES FROM WEST REPRODUCING STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM NORTHEAST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 20 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +5.0 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS + 0.8 FT MLLW
MOORING AREA SWEPT TO 30-FT DEPTH
SMALL BOAT HAVEN
FILL AREA IS UNDERMINED BY WAVE ACTION
CELLULAR BREAKWATER
SUBMARINE BASIN
23-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
N
LATITUDE
LONGITUDE
SWAN ISLE
SHALLOW WATER
SLACK
EASTERN ISLAND CHANNEL
30-FT DEPTH
EASTERN ISLAND
UNDERMINED BY WAVE ACTION
LIMIT OF UNDERMINING
SPOIL
SHALLOW WATER
SPOIL
CORAL REEF
CORAL REEF
25
49
45
107
103
212
199
209
179
159
150
400-FT WIDTH
ENTRANCE
CHANNEL
NOTE CURRENTS OF LESS THAN 4 FEET PER SECOND ARE NOT SHOWN TO SCALE
THE ELEMENTS OF PLAN 8 CONSIST OF AN IMPERVIOUS BREAKWATER ALIGNED NORTHWARD FROM THE NORTHWEST CORNER OF SAND ISLAND TO THE BEGINNING OF THE CORAL REEF ON THE NORTH RIM OF THE ATOLL
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION, AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
PACIFIC OCEAN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS-PLAN 8
WAVES FROM NORTHEAST REPRODUCING WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1945
SCALES
PROTOTYPE
MODEL




**LEGEND**

BASE TEST — PLANS
CURRENT MAGNITUDE

BASE TEST PROFILE
PLANS PROFILE.
MODEL OBSERVATION STATION NO I.
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER.

NOTES WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945.

NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN.

MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS

**COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES**

BASE TEST AND PLANS I, I A, AND 2
20 FOOT WAVES FROM WEST DIRECTION

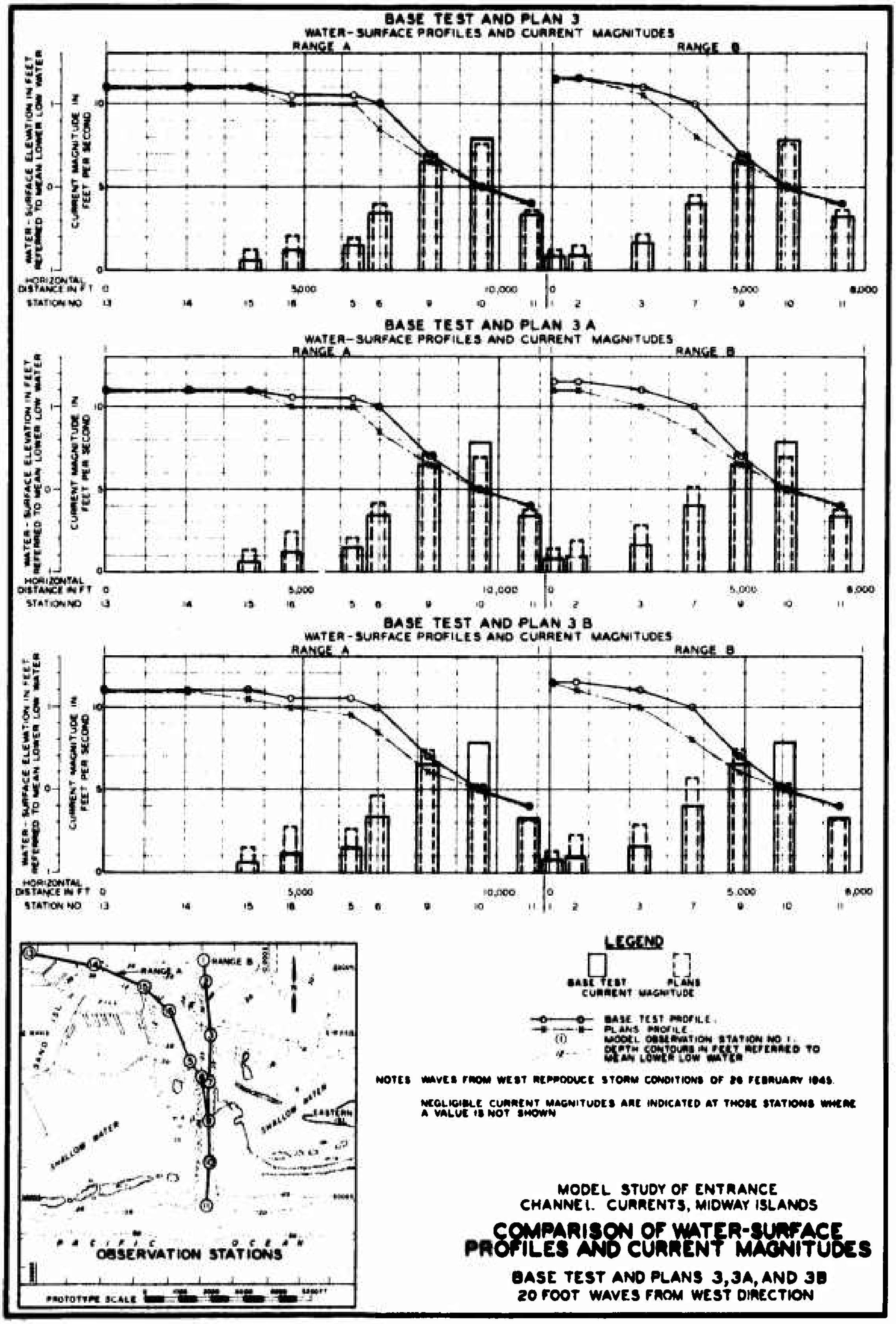
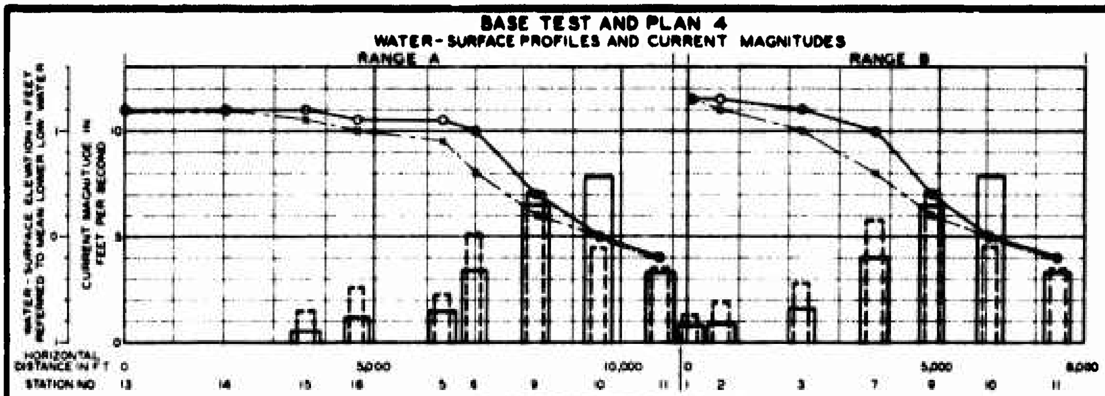
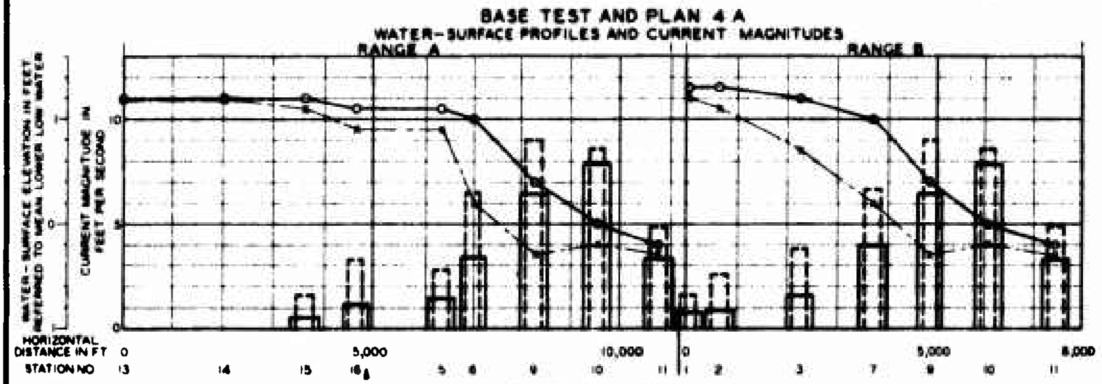
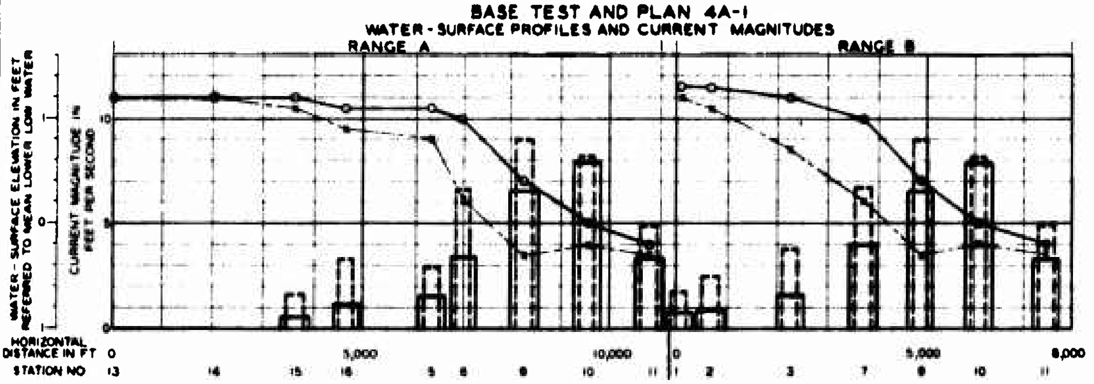
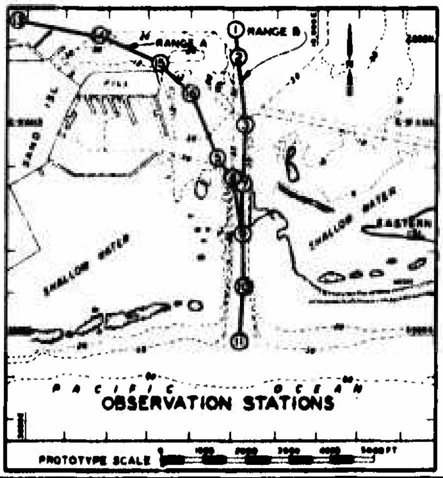

BASE TEST AND PLAN 3
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
RANGE A
RANGE B
WATER-SURFACE ELEVATION IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT MAGNITUDE IN FEET PER SECOND
HORIZONTAL DISTANCE IN FT
STATION NO
BASE TEST AND PLAN 3 A
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
BASE TEST AND PLAN 3 B
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
OBSERVATION STATIONS
PACIFIC OCEAN
SHALLOW WATER
PROTOTYPE SCALE
LEGEND
BASE TEST
PLANS
CURRENT MAGNITUDE
BASE TEST PROFILE
PLANS PROFILE
MODEL OBSERVATION STATION NO 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
NOTES WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1949.
NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN
MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS
COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
BASE TEST AND PLANS 3, 3A, AND 3B
20 FOOT WAVES FROM WEST DIRECTION

PLATE 31




**LEGEND**

BASE TEST — PLANS
CURRENT MAGNITUDE

BASE TEST PROFILE
PLANS PROFILE
MODEL OBSERVATION STATION NO 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

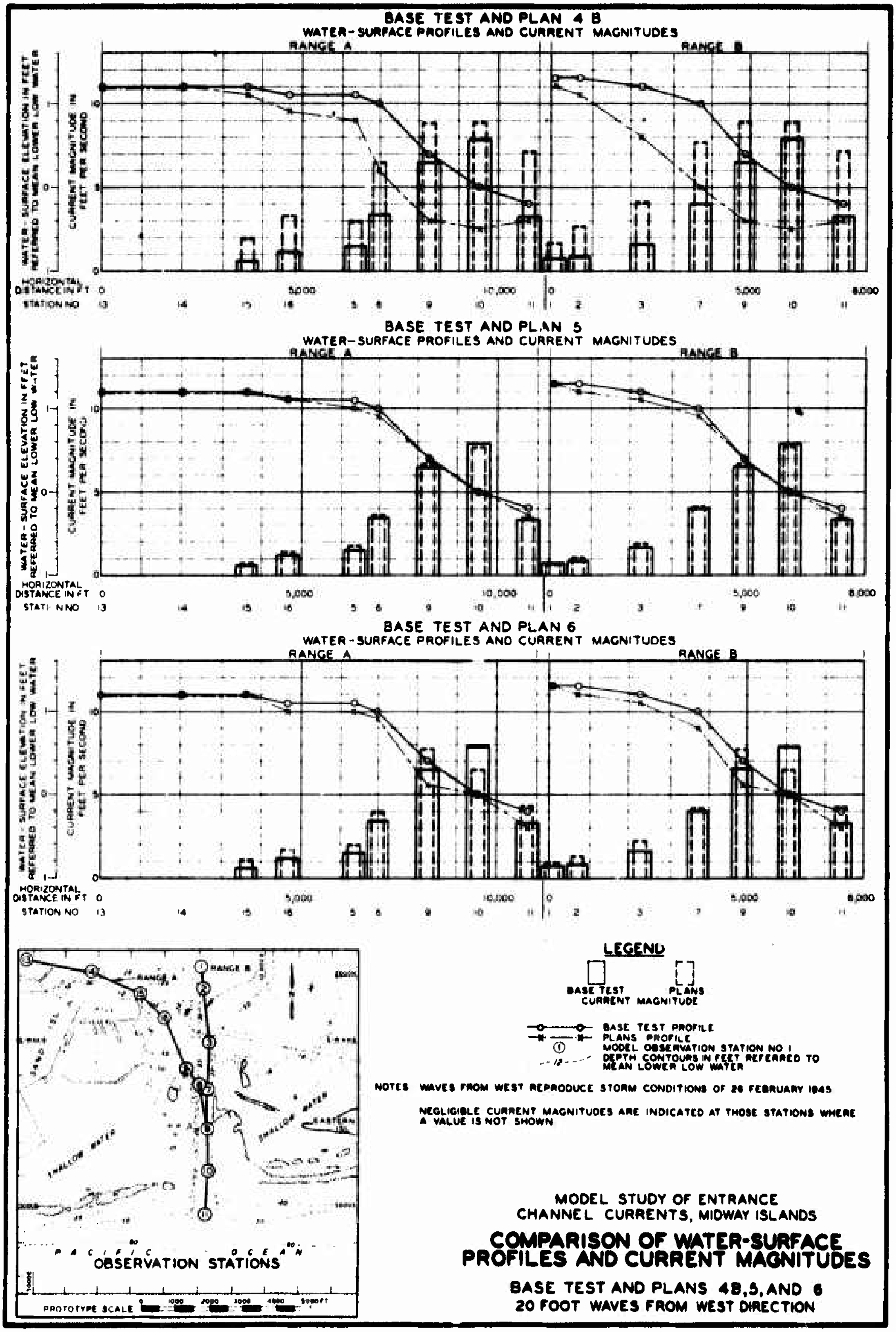
NOTES WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945.

NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN

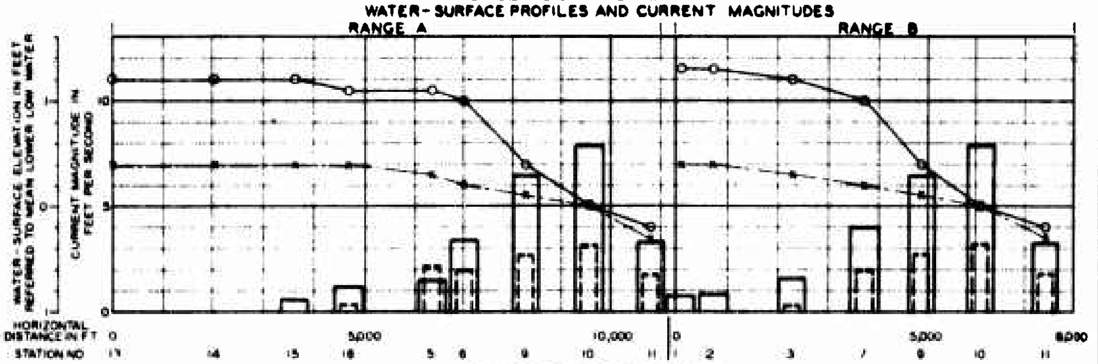
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

**COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES**

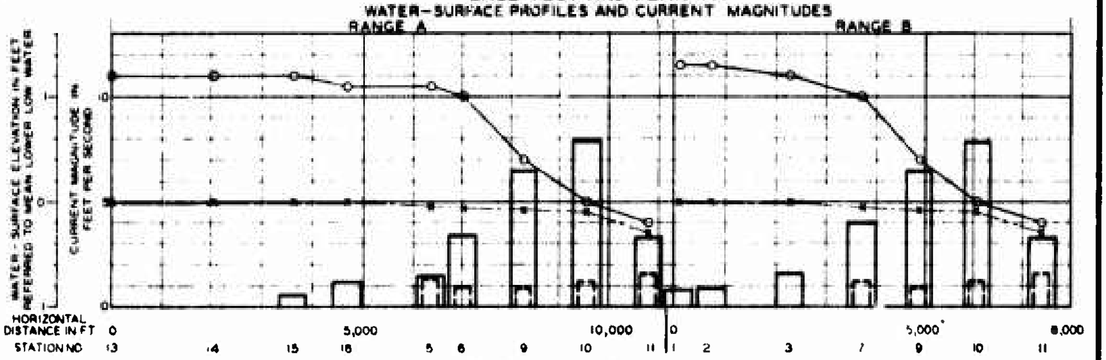
BASE TEST AND PLANS 4, 4A, AND 4A-1
20 FOOT WAVES FROM WEST DIRECTION


BASE TEST AND PLAN 4 B
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
RANGE A
RANGE B
BASE TEST AND PLAN 5
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
BASE TEST AND PLAN 6
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
WATER - SURFACE ELEVATION IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT MAGNITUDE IN FEET PER SECOND
HORIZONTAL DISTANCE IN FT
STATION NO
OBSERVATION STATIONS
PACIFIC OCEAN
SHALLOW WATER
PROTOTYPE SCALE
LEGEND
BASE TEST
PLANS
CURRENT MAGNITUDE
BASE TEST PROFILE
PLANS PROFILE
MODEL OBSERVATION STATION NO 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
NOTES WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945
NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES
BASE TEST AND PLANS 4B, 5, AND 6
20 FOOT WAVES FROM WEST DIRECTION

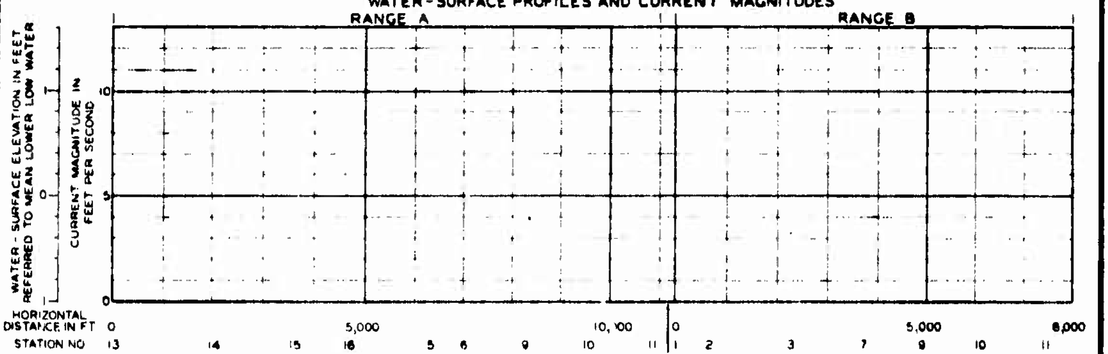
BASE TEST AND PLAN 7
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES

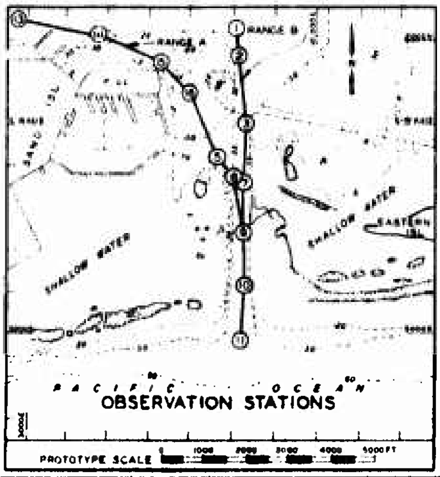



BASE TEST AND PLAN 7A
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES




BASE TEST AND PLAN
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES




OBSERVATION STATIONS

**LEGEND**

BASE TEST / PLANS
CURRENT MAGNITUDE

BASE TEST PROFILE.
PLANS PROFILE.
MODEL OBSERVATION STATION NO 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

NOTES: WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945

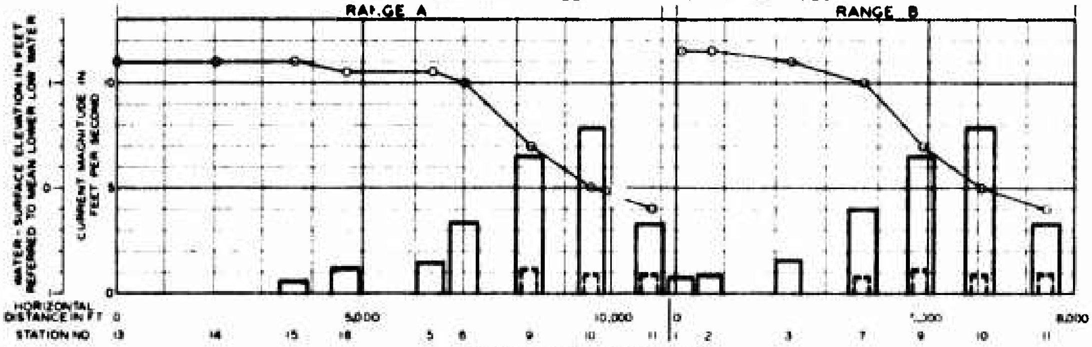
NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN.

MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS

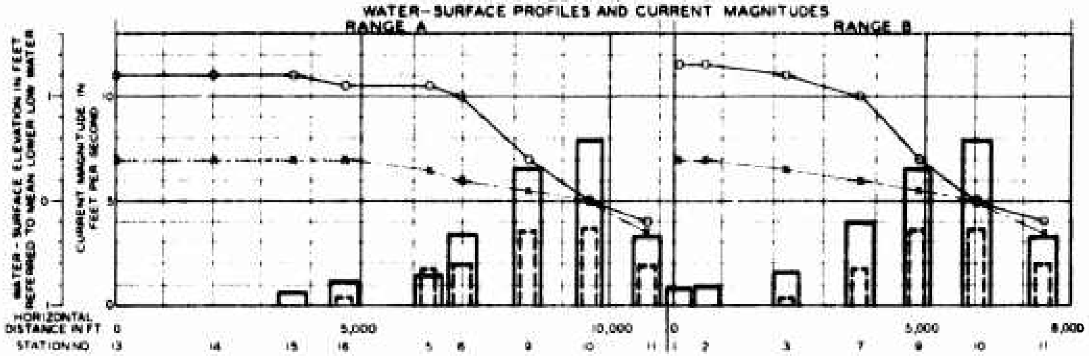
**COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES**

BASE TEST AND PLANS 7 AND 7A
20 FOOT WAVES FROM WEST DIRECTION

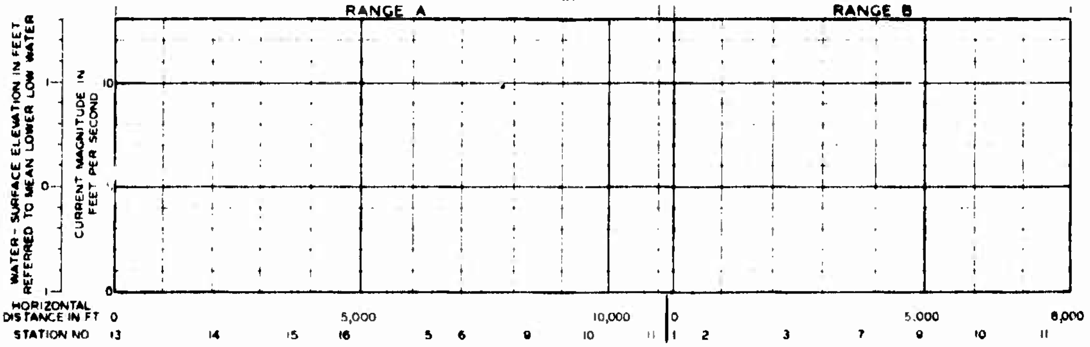
## BASE TEST AND PLAN 7B
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES

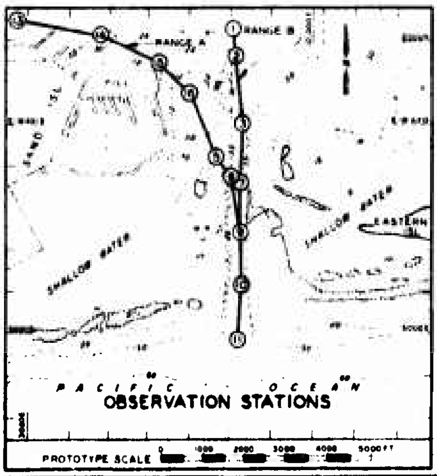



## BASE TEST AND PLAN 8
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES




## BASE TEST AND PLAN
WATER-SURFACE PROFILES AND CURRENT MAGNITUDES




OBSERVATION STATIONS

**LEGEND**

BASE TEST / PLANS
CURRENT MAGNITUDE

BASE TEST PROFILE
PLANS PROFILE
MODEL OBSERVATION STATION NO 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

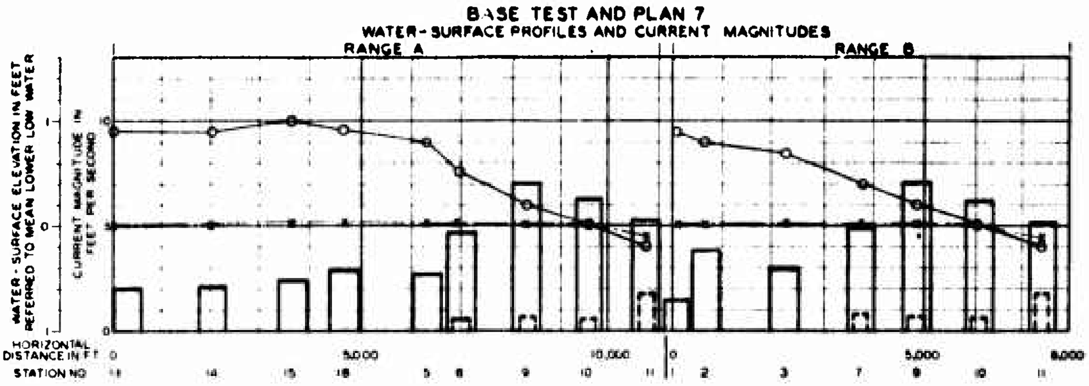
NOTES WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945

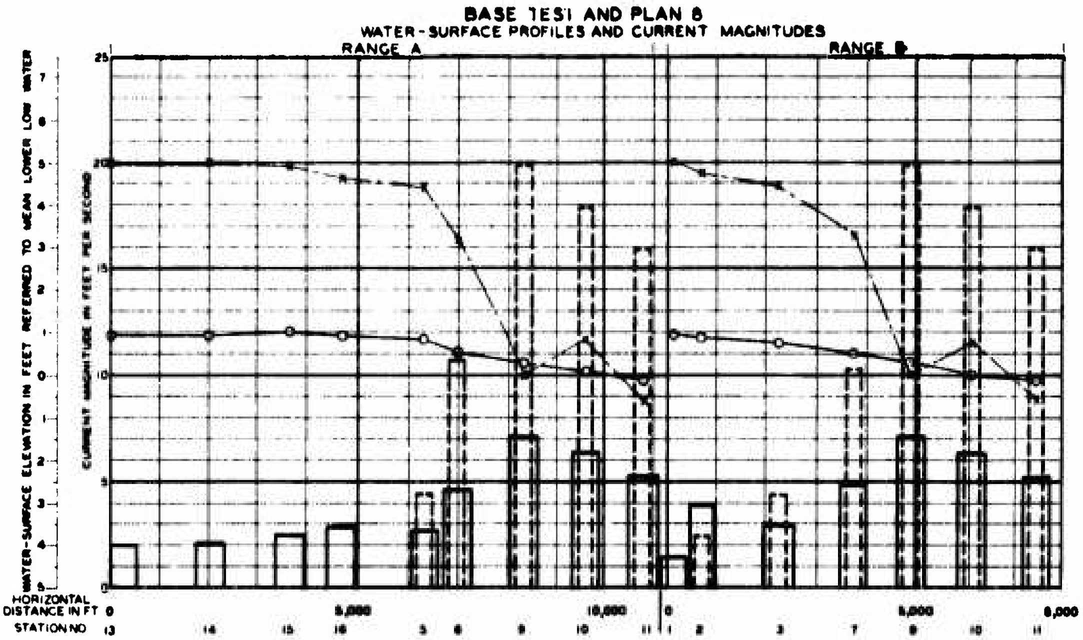
NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN

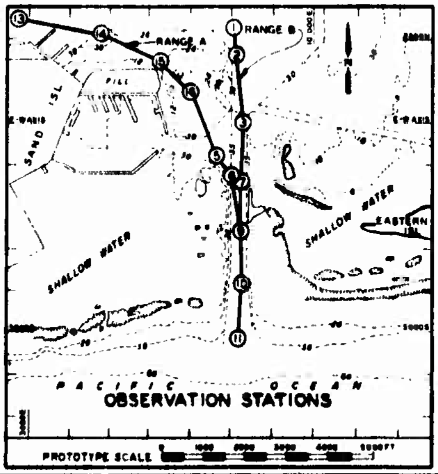
MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS

**COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES**

BASE TEST AND PLANS 7B AND 8
20 FOOT WAVES FROM WEST DIRECTION




**LEGEND**

BASE TEST — PLANS
CURRENT MAGNITUDE

BASE TEST PROFILE
PLANS PROFILE
MODEL OBSERVATION STATION NO 1
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

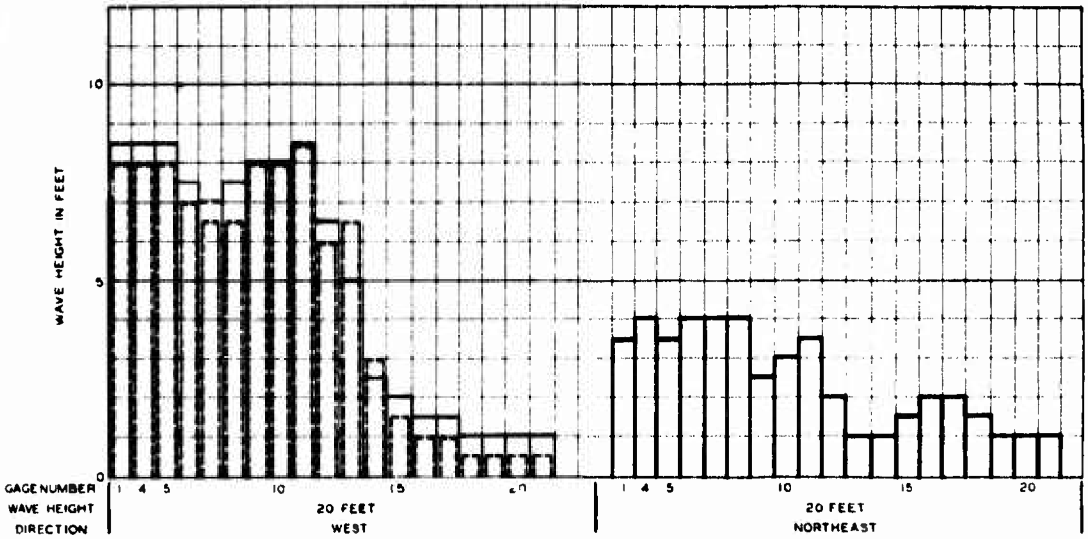
NOTES: WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1945

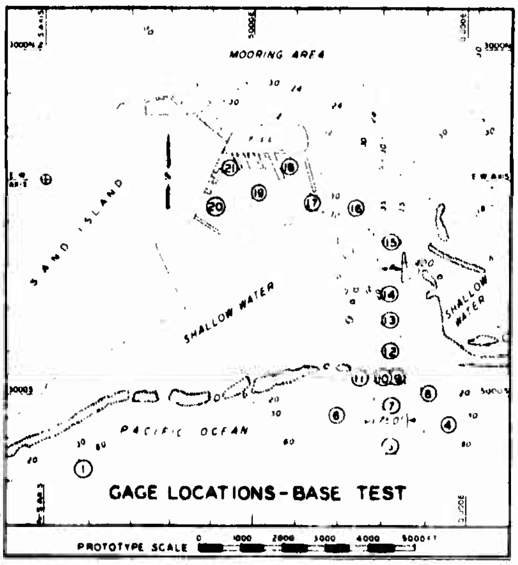
NEGLIGIBLE CURRENT MAGNITUDES ARE INDICATED AT THOSE STATIONS WHERE A VALUE IS NOT SHOWN.

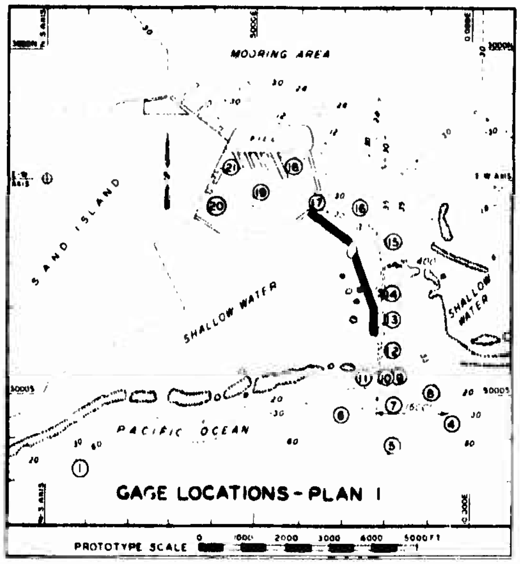
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

**COMPARISON OF WATER-SURFACE PROFILES AND CURRENT MAGNITUDES**

BASE TEST AND PLANS 7 AND 8
20 FOOT WAVES FROM NORTHEAST DIRECTION




NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1945

LEGEND

BASE TEST PLAN I

⑦ MODEL GAGE NUMBER 7

12 DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

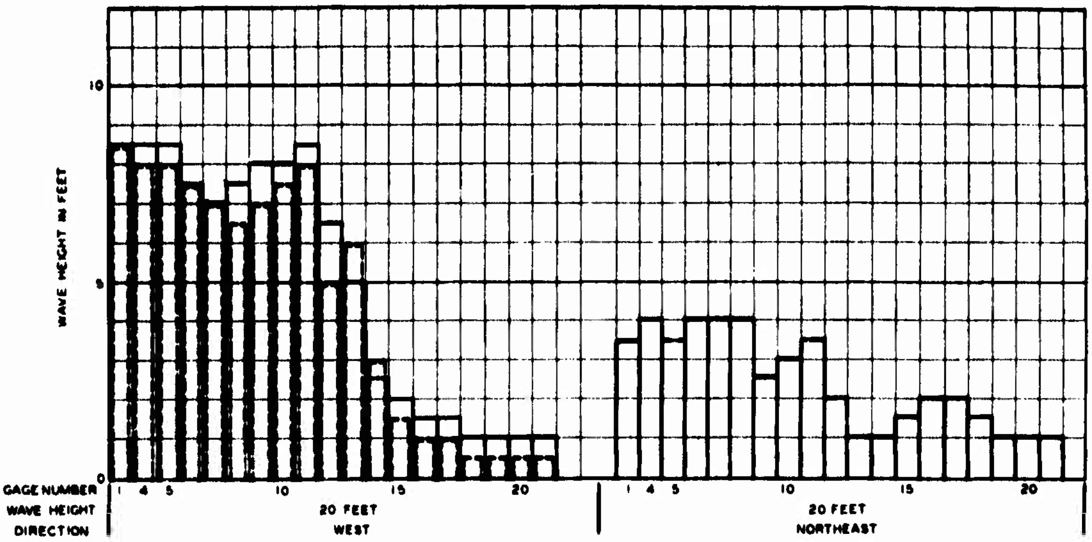
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

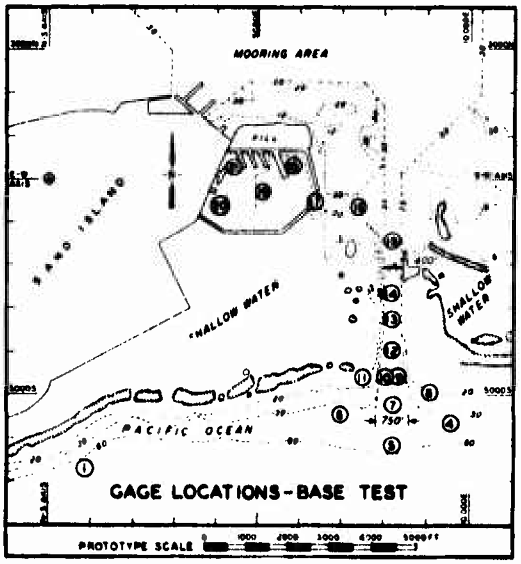
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

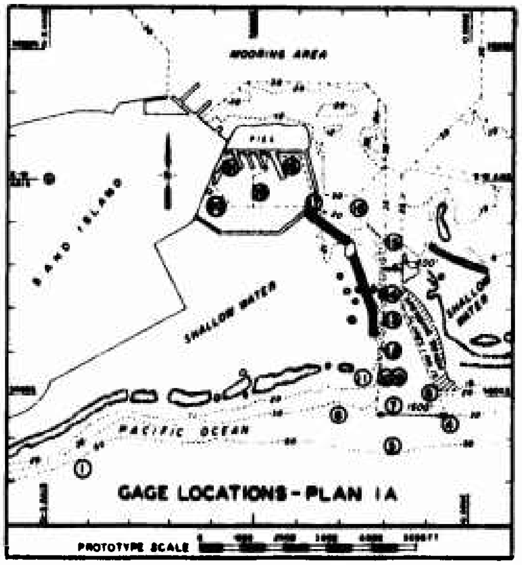
**COMPARISON OF WAVE HEIGHTS**

BASE TEST AND PLAN I

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS. THE LOCATION OF THESE GAGES ARE AS FOLLOWS:

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1948.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1948.

LEGEND

BASE TEST — PLAN IA

⑦ MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

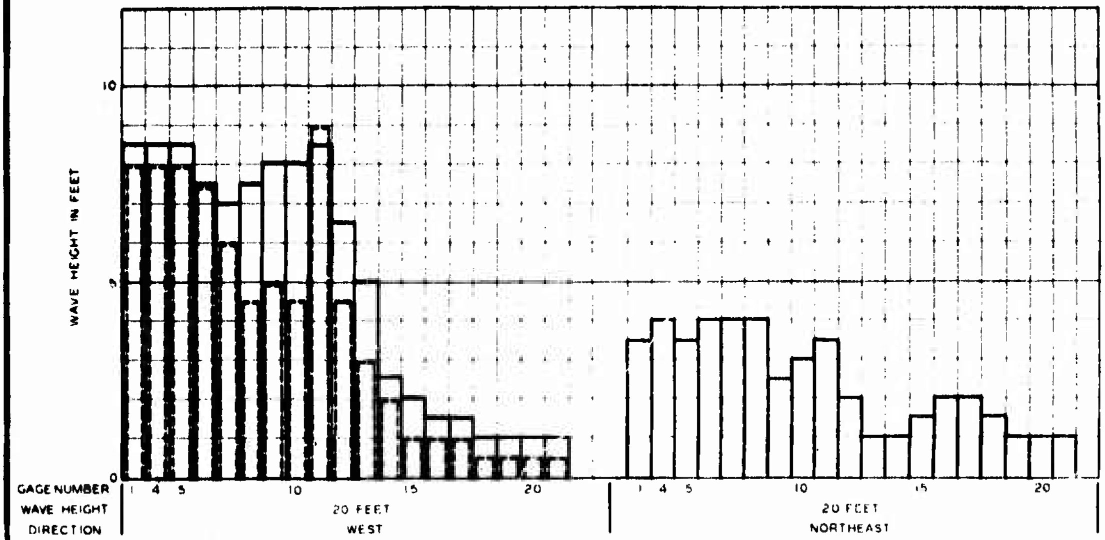
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

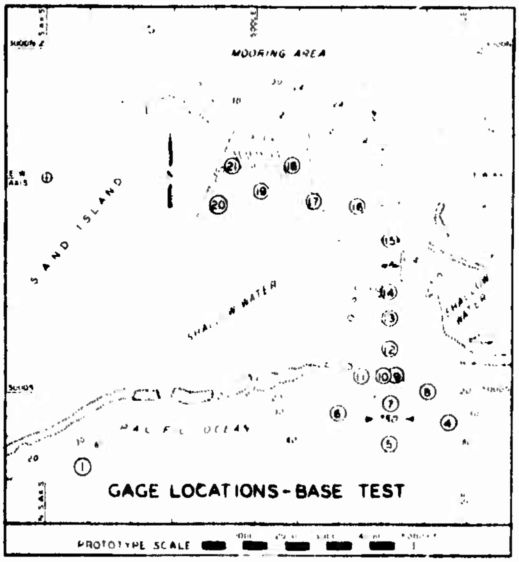
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

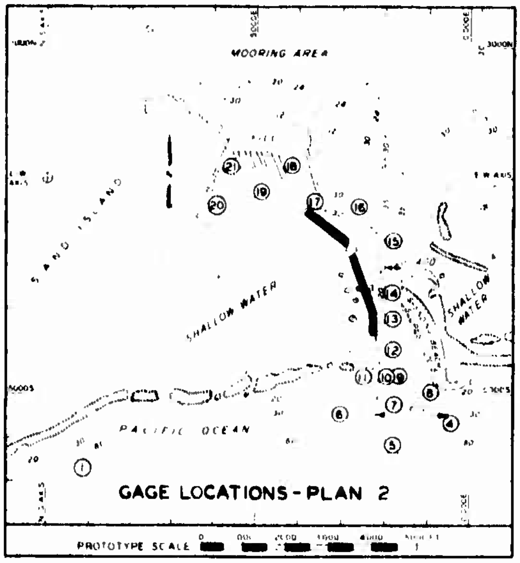
COMPARISON OF WAVE HEIGHTS

BASE TEST AND PLAN IA

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1946

LEGEND

BASE TEST — PLAN 2

(7) MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

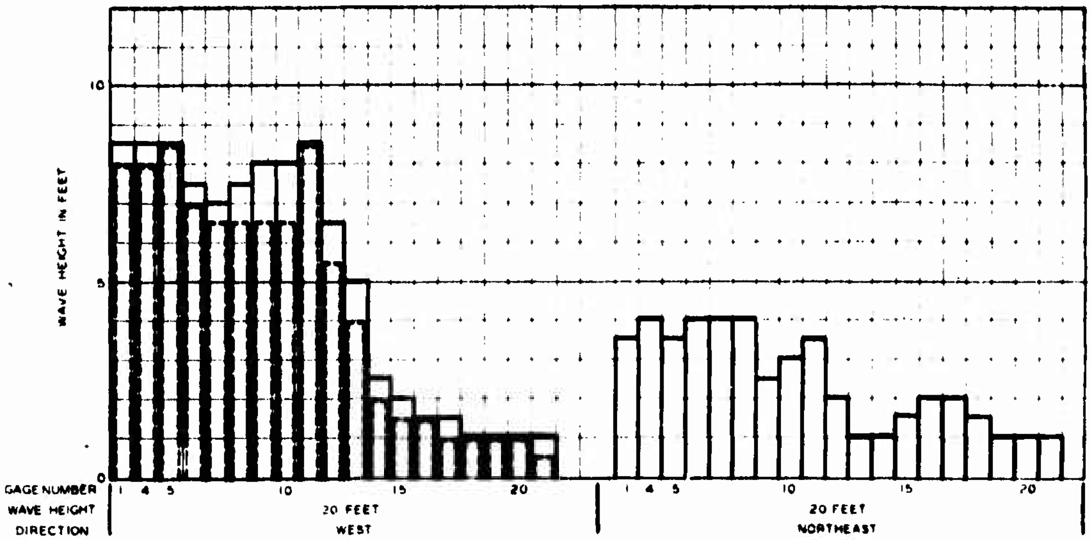
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +10 FT MLLW)

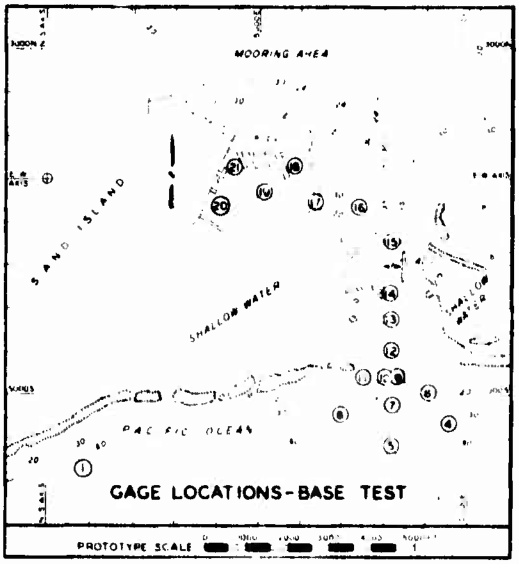
MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS

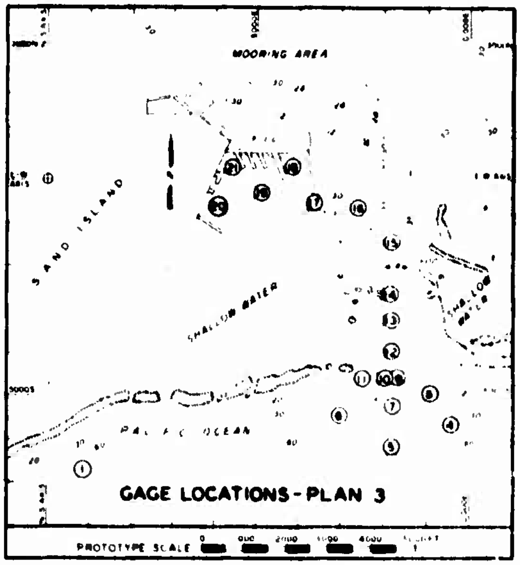
## COMPARISON OF WAVE HEIGHTS

BASE TEST AND PLAN 2

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1946.

LEGEND

BASE TEST PLAN 3

⑦ MODEL GAGE NUMBER 7

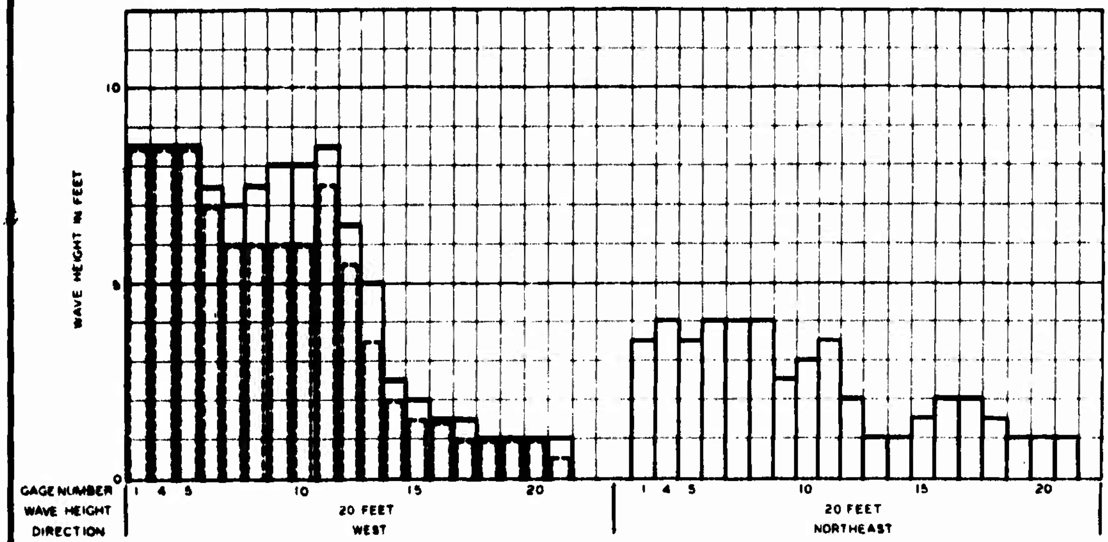
12 DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

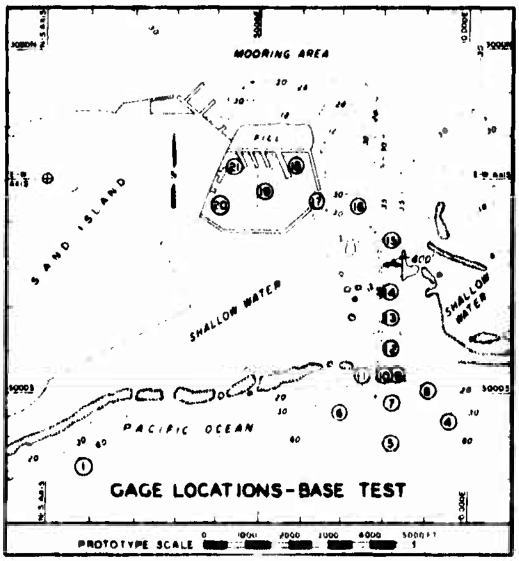
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

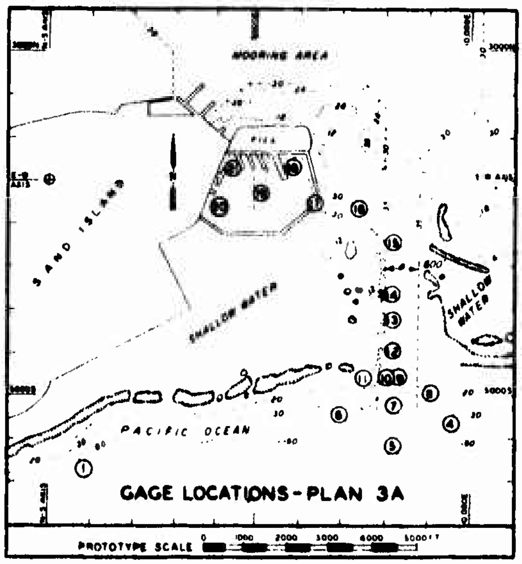
BASE TEST AND PLAN 3

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




GAGE LOCATIONS - BASE TEST




GAGE LOCATIONS - PLAN 3A

NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,850 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1946.

**LEGEND**

BASE TEST — PLAN 3A

⑦ MODEL GAGE NUMBER 7

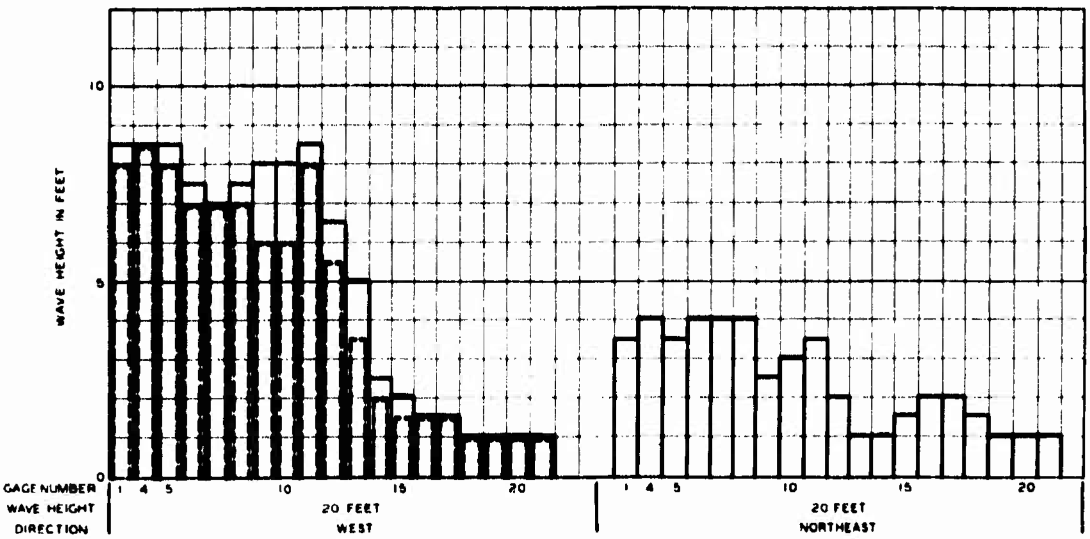
14 DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

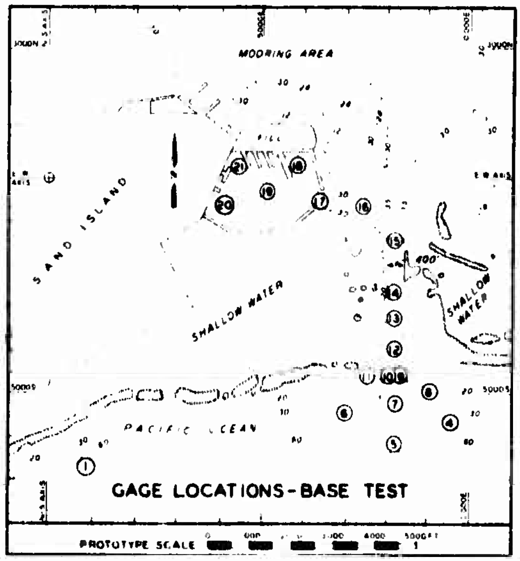
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

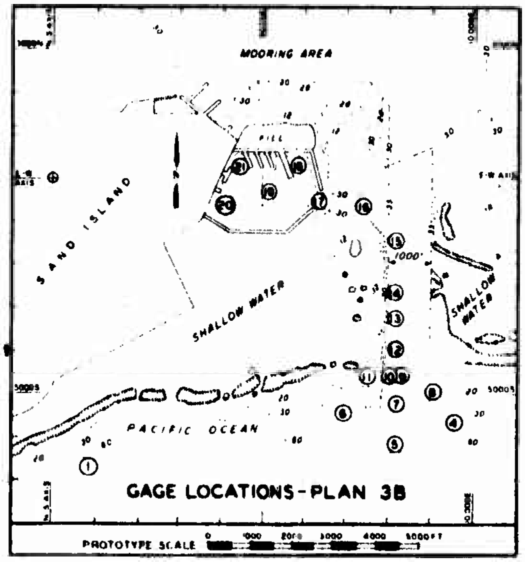
BASE TEST AND PLAN 3A

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




GAGE LOCATIONS - BASE TEST




GAGE LOCATIONS - PLAN 3B

NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS:

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1946

## LEGEND

BASE TEST — PLAN 3B

⑦ MODEL GAGE NUMBER 7

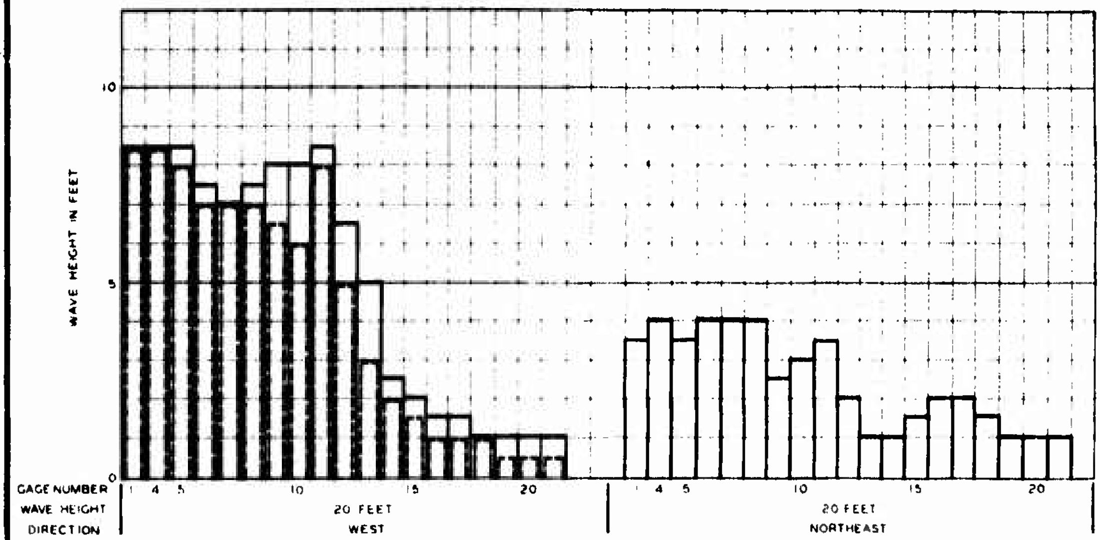
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

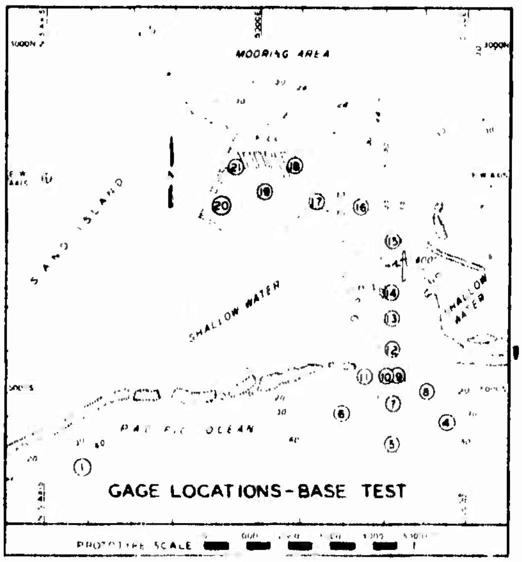
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

# COMPARISON OF WAVE HEIGHTS

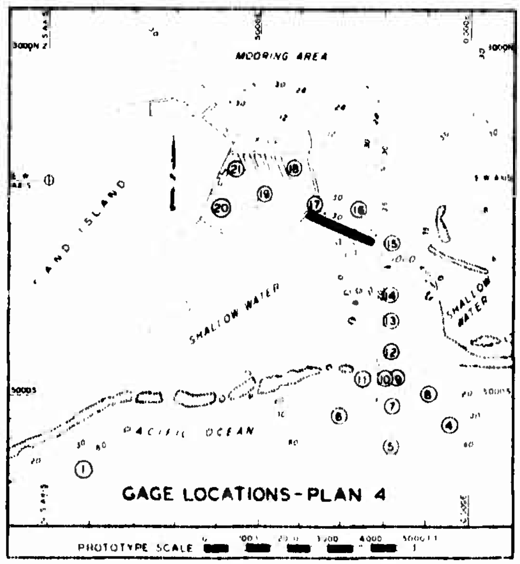
## BASE TEST AND PLAN 3B

### 20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




GAGE LOCATIONS - BASE TEST




GAGE LOCATIONS - PLAN 4

NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1946

**LEGEND**

BASE TEST PLAN 4

(7) MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

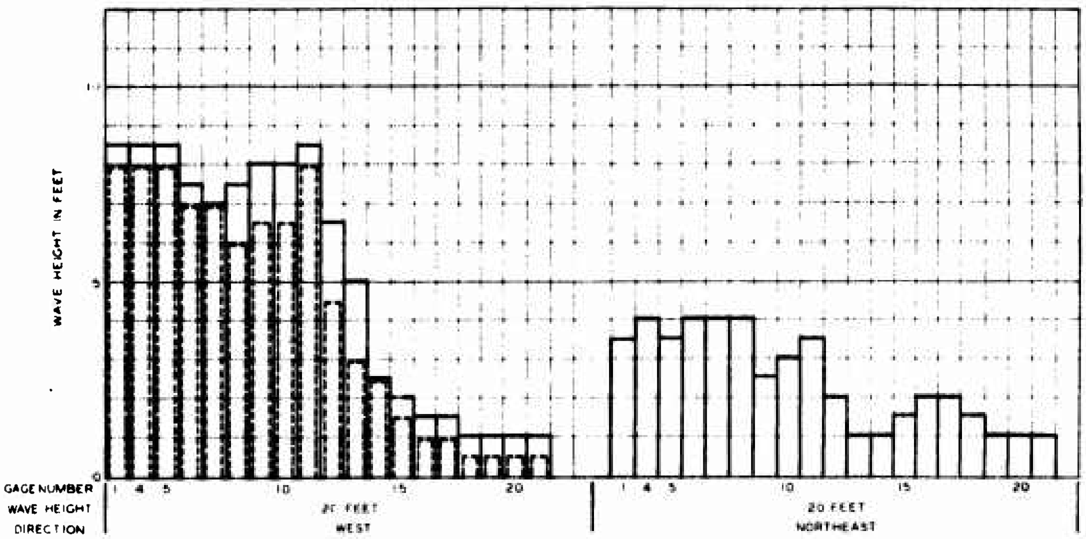
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

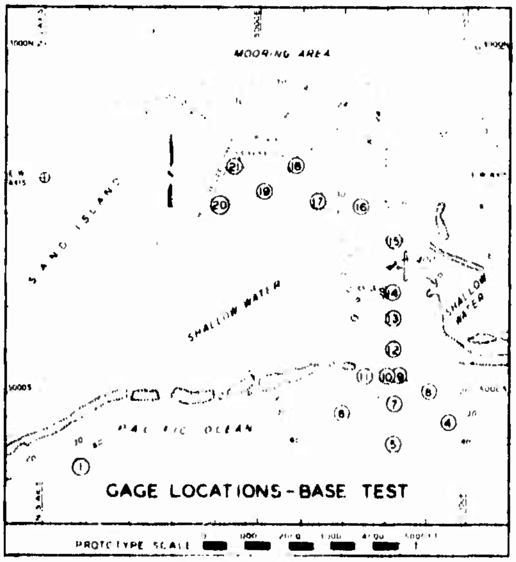
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

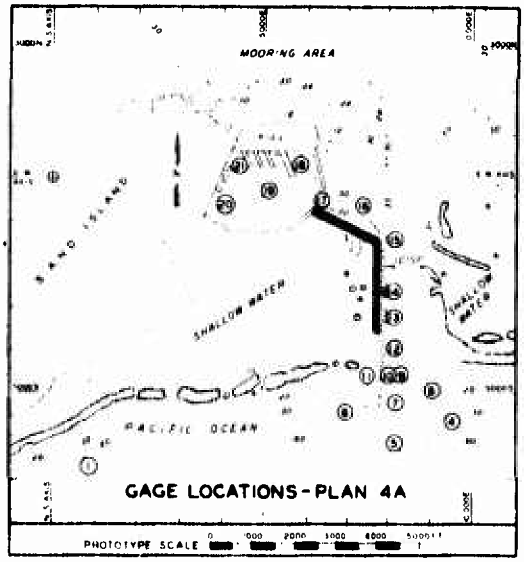
BASE TEST AND PLAN 4

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




GAGE LOCATIONS - BASE TEST




GAGE LOCATIONS - PLAN 4A

NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1946

LEGEND

BASE TEST PLAN 4A

(7) MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

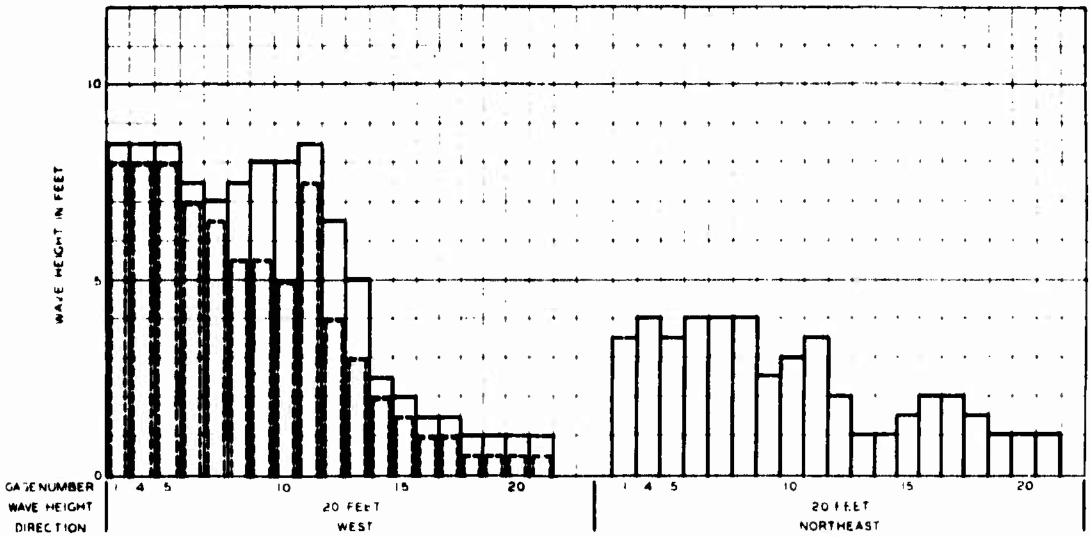
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

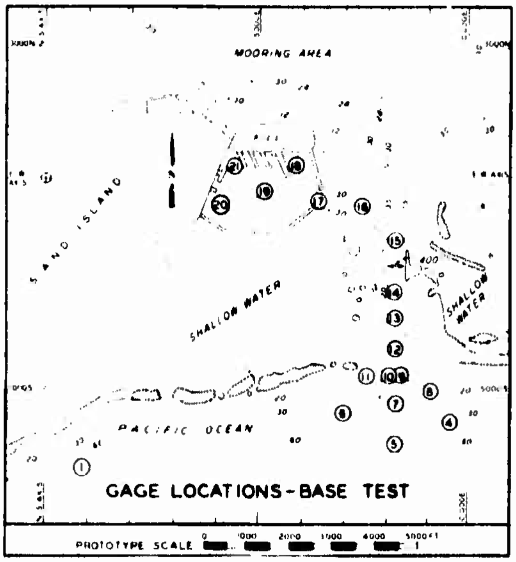
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

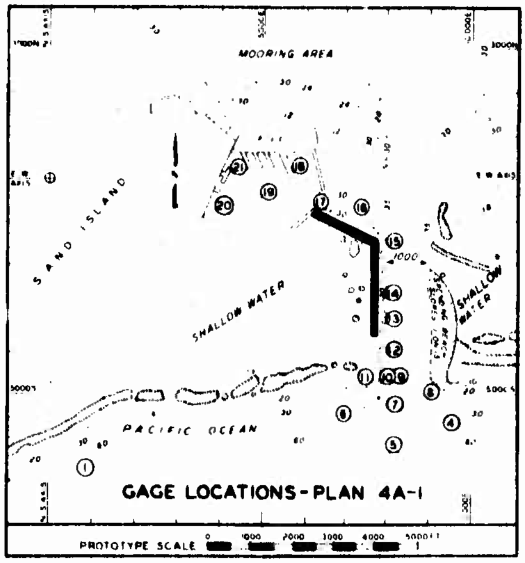
BASE TEST AND PLAN 4A

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS



GAGE LOCATIONS - BASE TEST



GAGE LOCATIONS - PLAN 4A-1

NOTES: GAGES NOS. 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS. THE LOCATION OF THESE GAGES ARE AS FOLLOWS:

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1946

LEGEND

BASE TEST — PLAN 4A-1

(7) MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

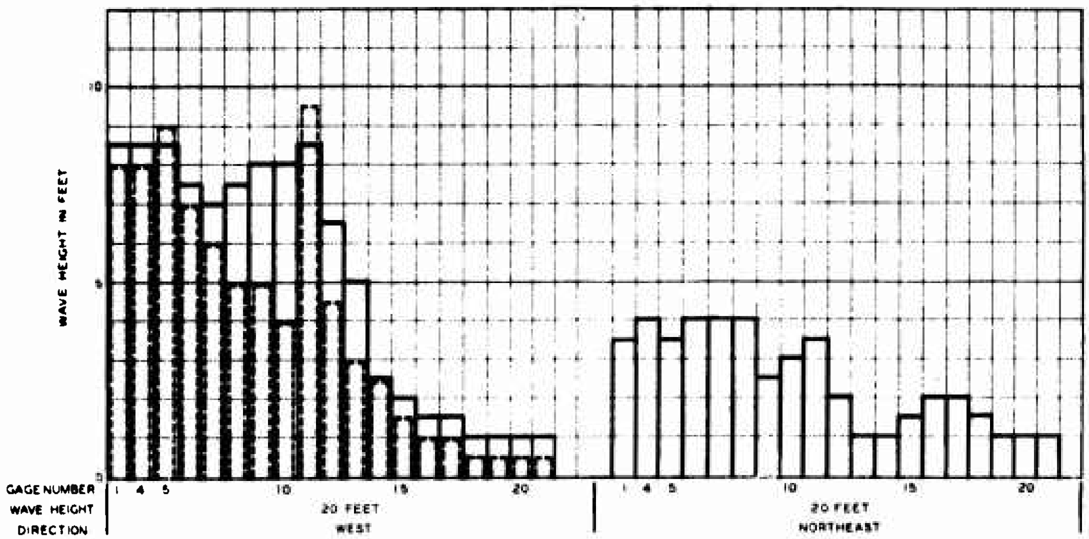
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

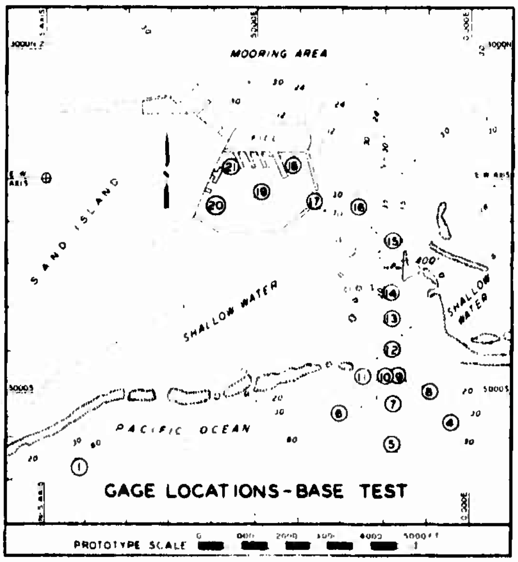
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

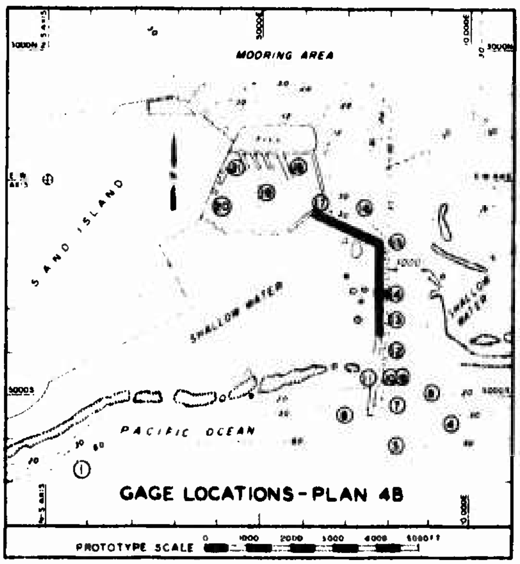
## COMPARISON OF WAVE HEIGHTS

BASE TEST AND PLAN 4A-1

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




NOTES: GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS. THE LOCATION OF THESE GAGES ARE AS FOLLOWS:

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1946.

LEGEND

BASE TEST — PLAN 4B

(7) MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

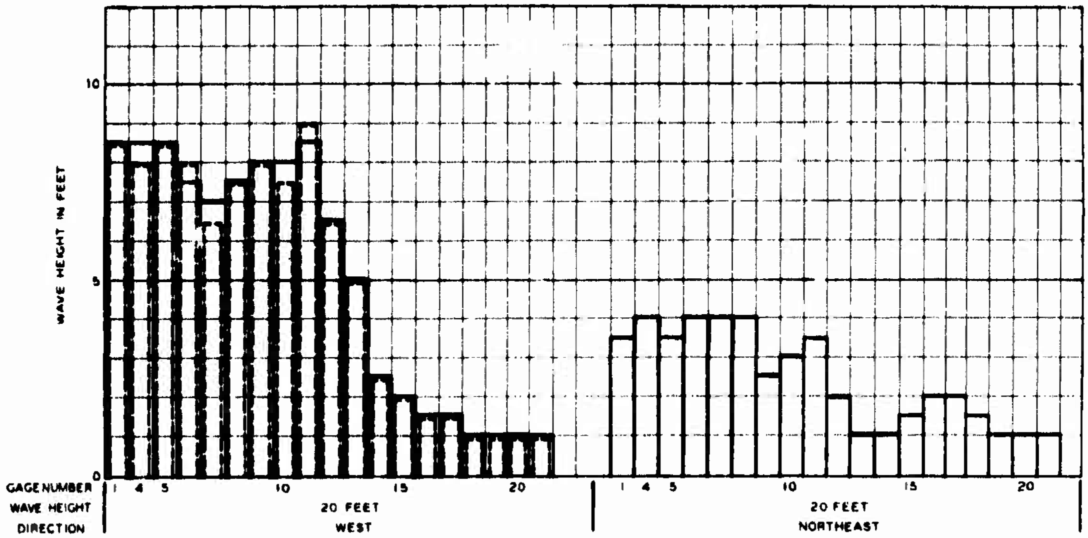
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +10 FT MLLW)

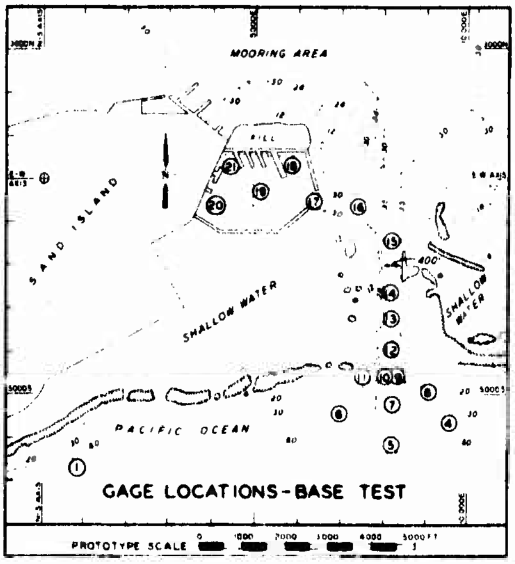
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

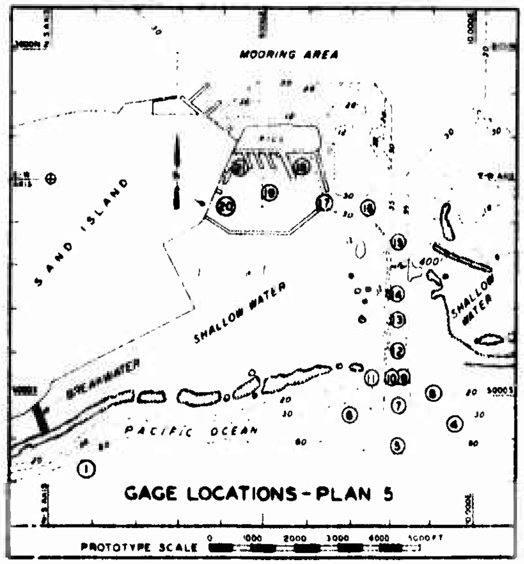
BASE TEST AND PLAN 4 B

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




GAGE LOCATIONS - BASE TEST




GAGE LOCATIONS - PLAN 5

NOTES: GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS. THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1946

**LEGEND**

BASE TEST PLAN 5

⑦ MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

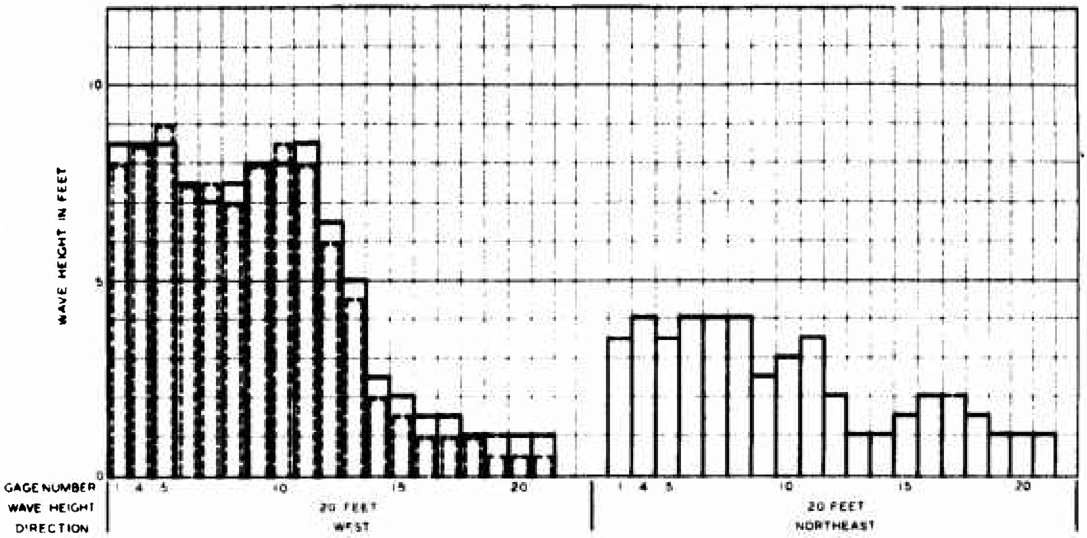
PROPOSED BREAKWATER LOCATION (TOP ELEVATION + 7 FT MLLW)

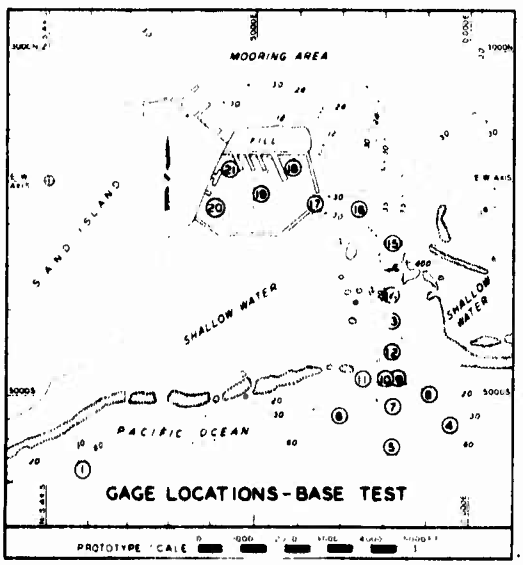
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

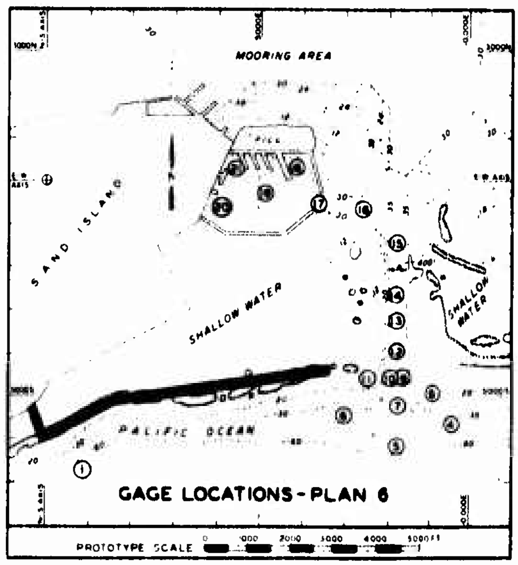
BASE TEST AND PLAN 5

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS



GAGE LOCATIONS - BASE TEST



GAGE LOCATIONS - PLAN 6

NOTES: GAGES NOS. 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS. THE LOCATION OF THESE GAGES ARE AS FOLLOWS:

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N 3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1946.

**LEGEND**

BASE TEST — PLAN 6

⑦ MODEL GAGE NUMBER 7

10 DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

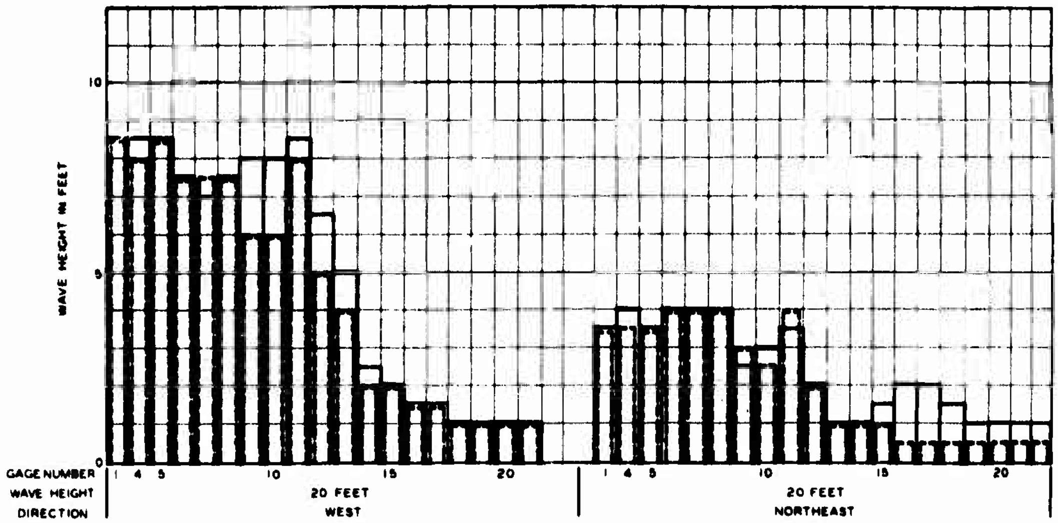
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

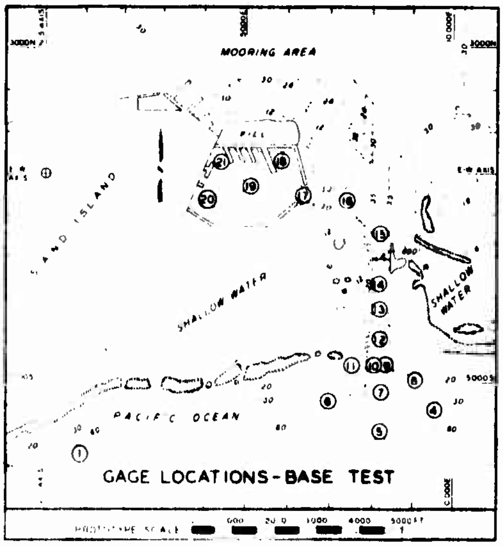
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

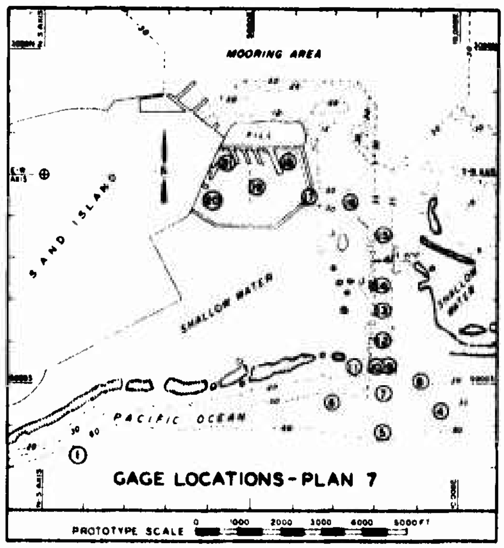
## COMPARISON OF WAVE HEIGHTS

BASE TEST AND PLAN 6

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E 1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1945

THE ELEMENTS OF PLAN 7 CONSIST OF AN IMPERVIOUS BREAKWATER WHICH INCLOSES THE DEEP-WATER AREA OF THE CENTRAL LAGOON

LEGEND

BASE TEST PLAN 7

MODEL GAGE NUMBER 7

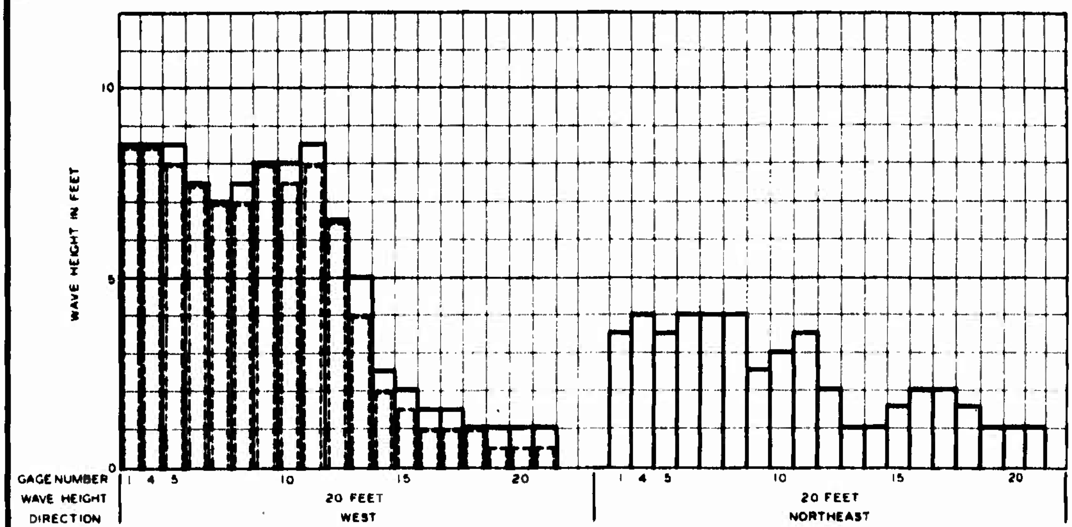
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

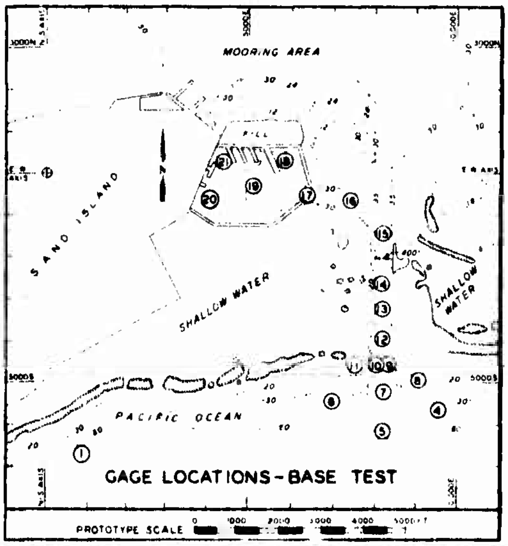
MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS

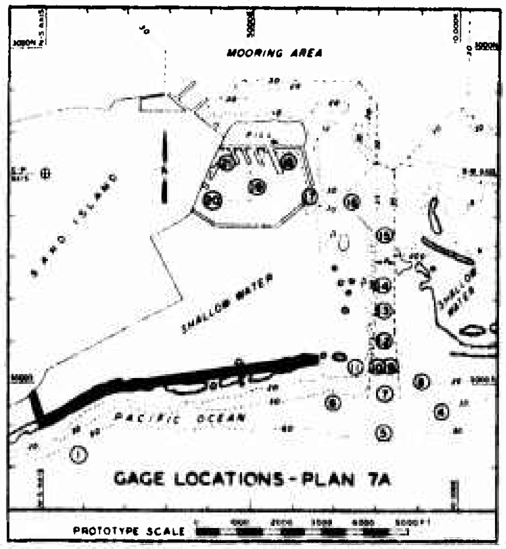
## COMPARISON OF WAVE HEIGHTS

BASE TEST AND PLAN 7

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 26 FEBRUARY 1945.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 26 FEBRUARY 1945

THE ELEMENTS OF PLAN 7A CONSIST OF AN IMPERVIOUS BREAKWATER WHICH INCLOSES THE DEEP-WATER AREA OF THE CENTRAL LAGOON PLUS THE ELEMENTS SHOWN ABOVE

## LEGEND

BASE TEST PLAN 7A

⑦ MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

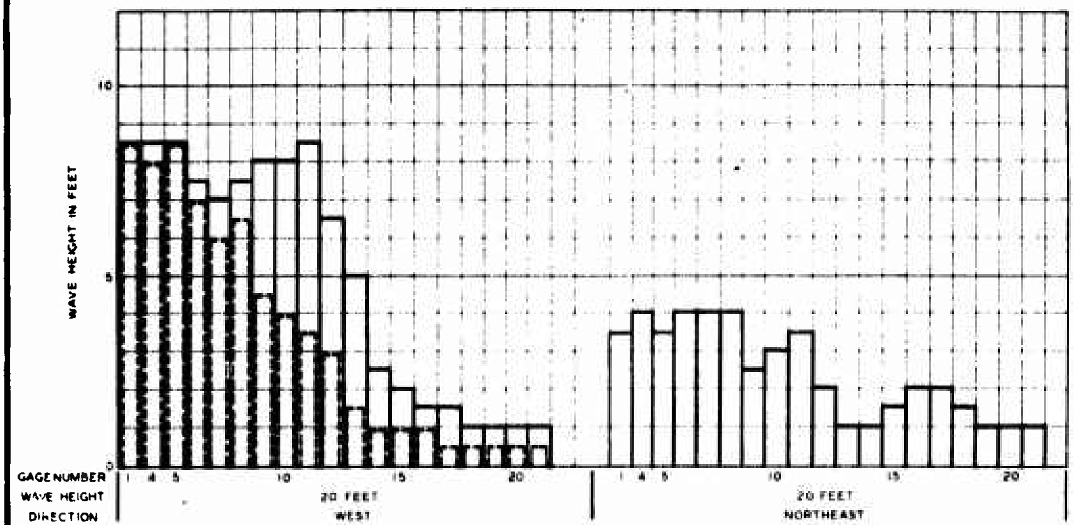
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7FT MLLW)

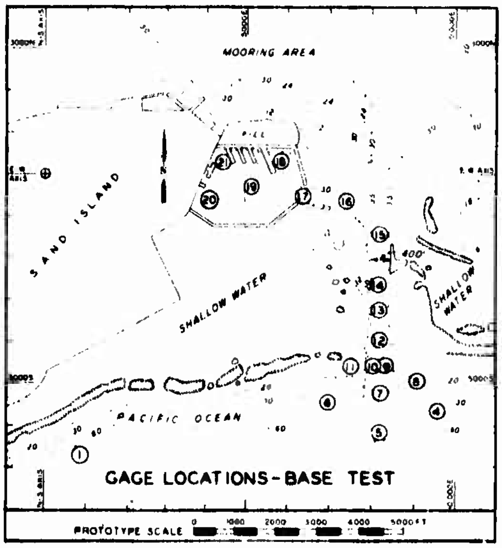
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

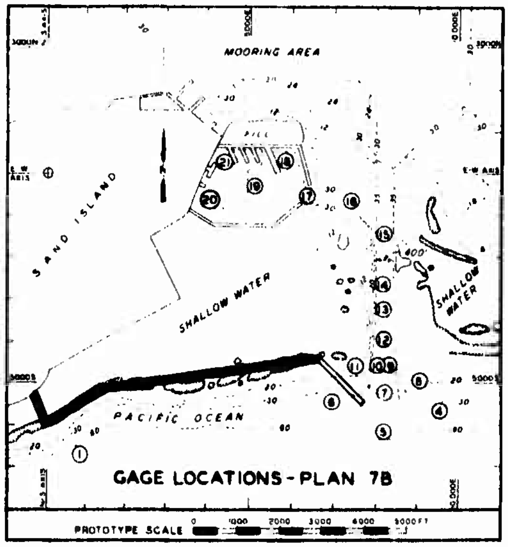
BASE TEST AND PLAN 7A

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS




GAGE LOCATIONS - BASE TEST




GAGE LOCATIONS - PLAN 7B

NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1945

THE ELEMENTS OF PLAN 7B CONSIST OF AN IMPERVIOUS BREAKWATER WHICH INCLOSES THE DEEP-WATER AREA OF THE CENTRAL LAGOON PLUS THE ELEMENTS SHOWN ABOVE

LEGEND

BASE TEST   PLAN 7B

⑦ MODEL GAGE NUMBER 7

10 DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

PROPOSED BREAKWATER LOCATION (TOP ELEVATION +7 FT MLLW)

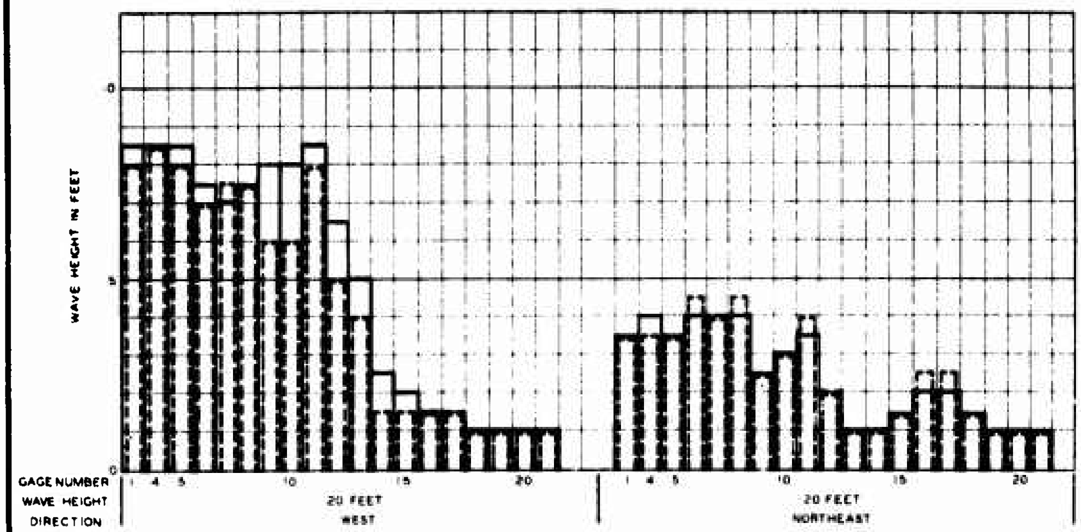
PROPOSED BREAKWATER LOCATION (TOP ELEVATION +10 FT MLLW)

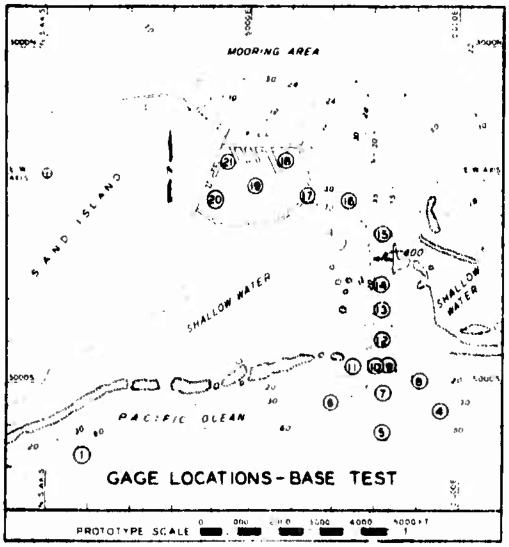
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

## COMPARISON OF WAVE HEIGHTS

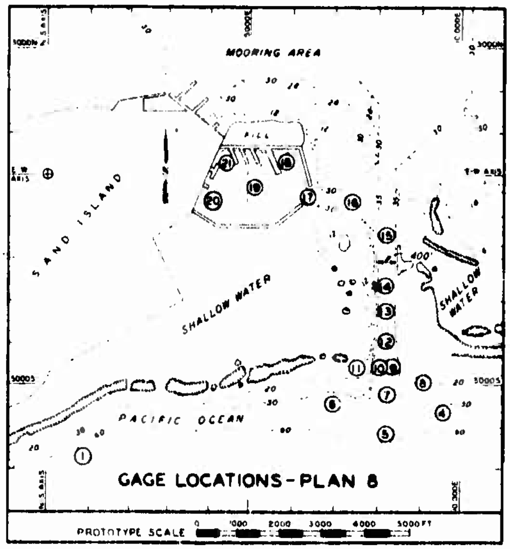
BASE TEST AND PLAN 7B

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS



GAGE LOCATIONS - BASE TEST



GAGE LOCATIONS - PLAN 8

NOTES GAGES NOS 2 AND 3 WERE USED FOR MEASURING WAVE HEIGHTS DURING MODEL ADJUSTMENT TESTS THE LOCATION OF THESE GAGES ARE AS FOLLOWS

| GAGE NO | LATITUDE | DEPARTURE |
|---|---|---|
| 2 | N3,150 FT | W14,750 FT |
| 3 | N24,750 FT | E1,950 FT |

WAVES FROM WEST REPRODUCE STORM CONDITIONS OF 28 FEBRUARY 1945.

WAVES FROM NORTHEAST REPRODUCE WAVE DIMENSIONS FOR STORM OF 28 FEBRUARY 1945

THE ELEMENTS OF PLAN 8 CONSIST OF AN IMPERVIOUS BREAKWATER ALIGNED NORTHWARD FROM THE NORTHWEST CORNER OF SAND ISLAND TO THE BEGINNING OF THE CORAL REEF ON THE NORTH RIM TO THE ATOLL.

LEGEND

BASE TEST PLAN 8

⑦ MODEL GAGE NUMBER 7

DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER

MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS

**COMPARISON OF WAVE HEIGHTS**

BASE TEST AND PLAN 8

20 FT WAVES FROM WEST AND NORTHEAST DIRECTIONS

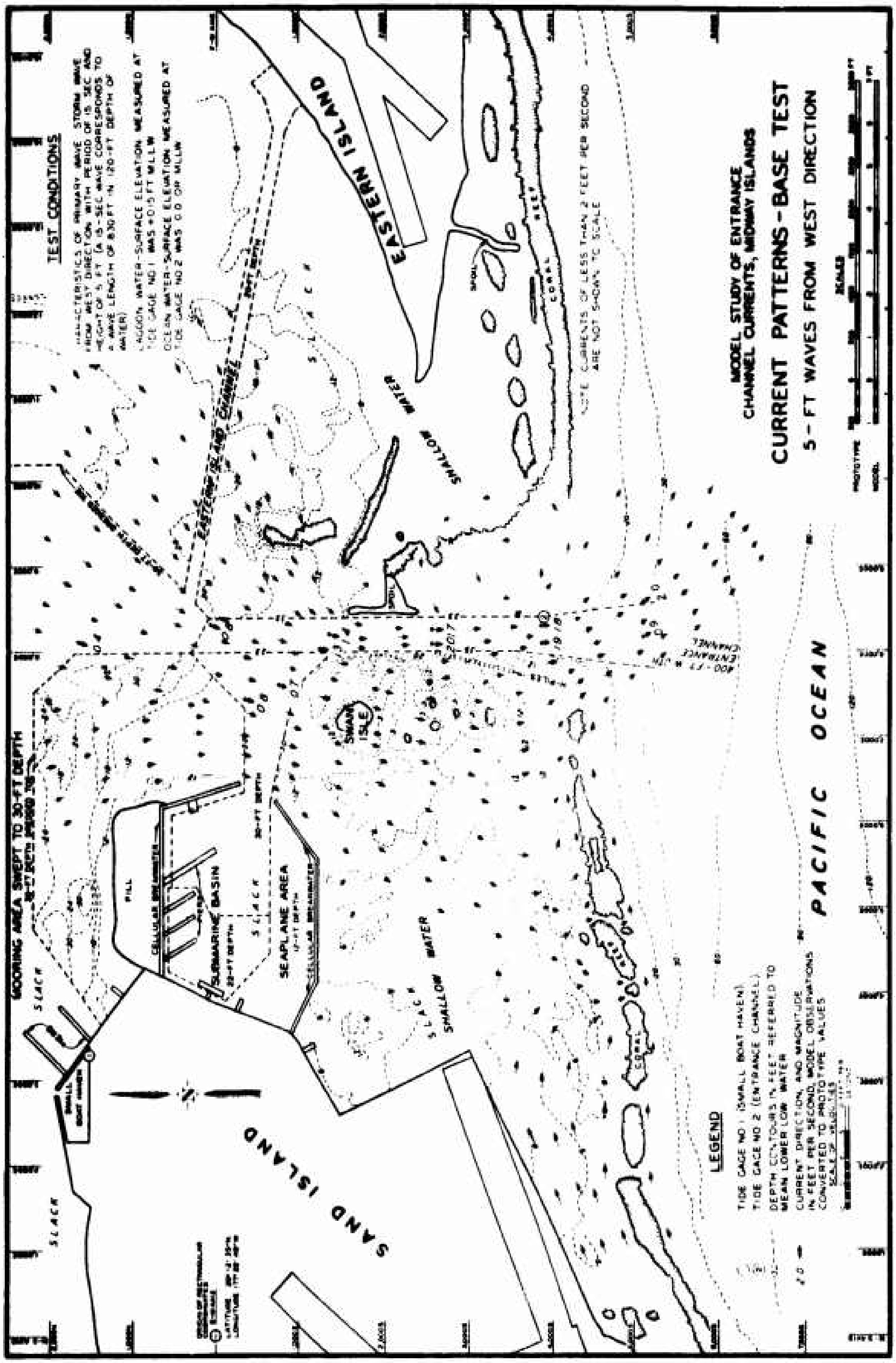

MODEL STUDY OF ENTRANCE
CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS - BASE TEST
5 - FT WAVES FROM WEST DIRECTION
TEST CONDITIONS
LEGEND
EASTERN ISLAND
SAND ISLAND
PACIFIC OCEAN
EASTERN ISLAND CHANNEL
SUBMARINE BASIN
SEAPLANE AREA
SHALLOW WATER
CORAL REEF
SLACK
FILL
MOORING AREA SWEPT TO 30-FT DEPTH
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE

PLATE 53

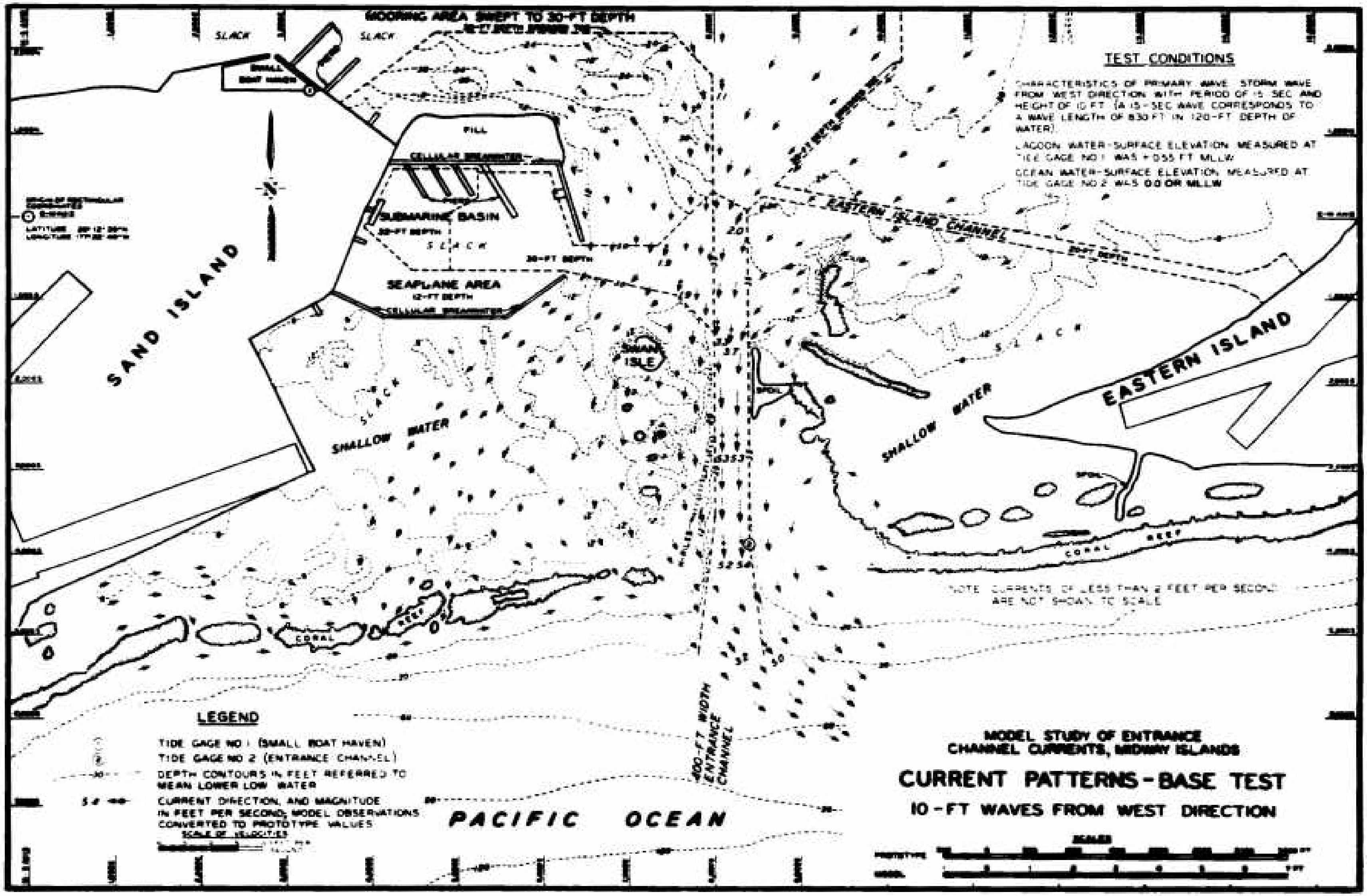
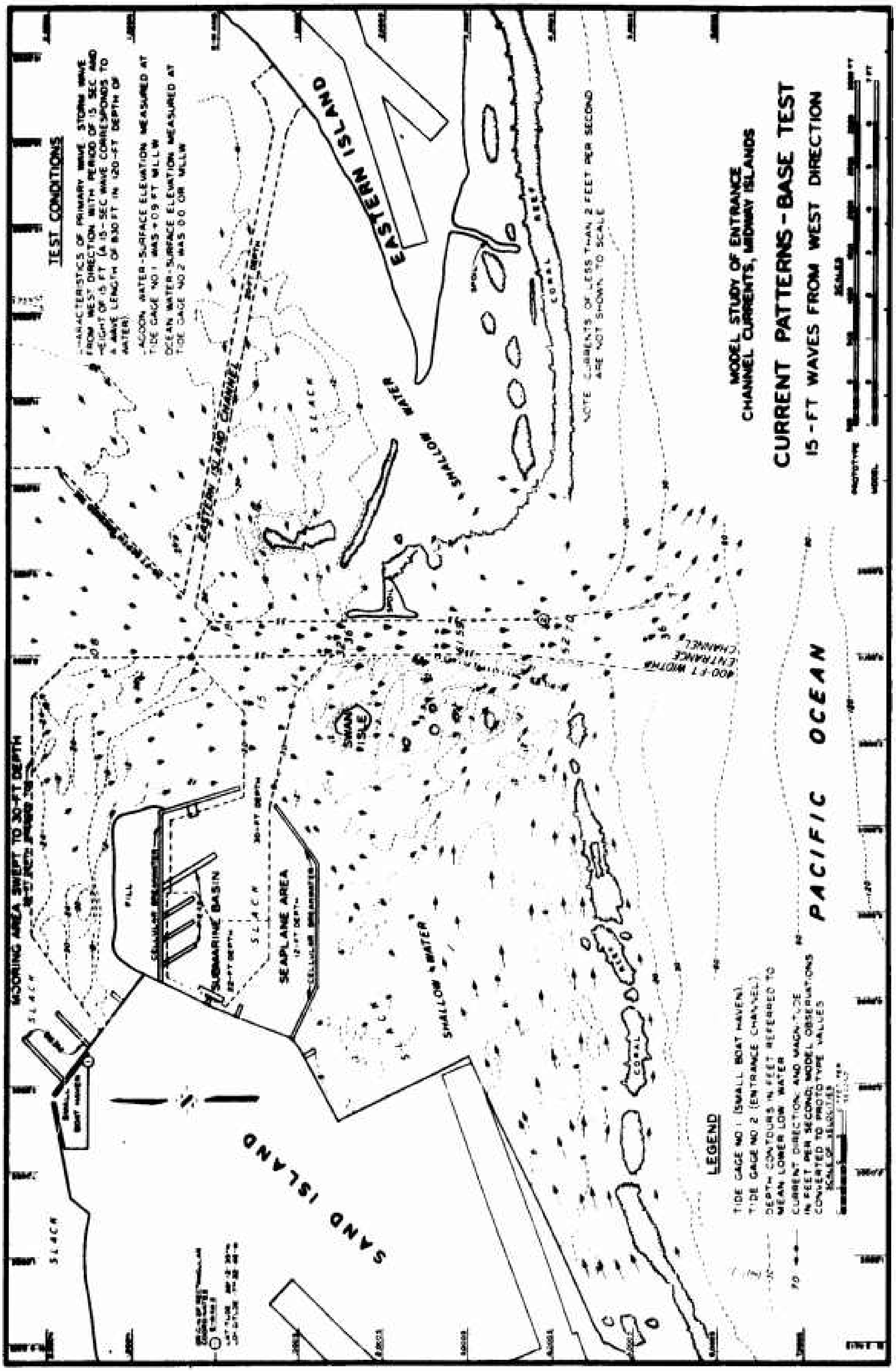
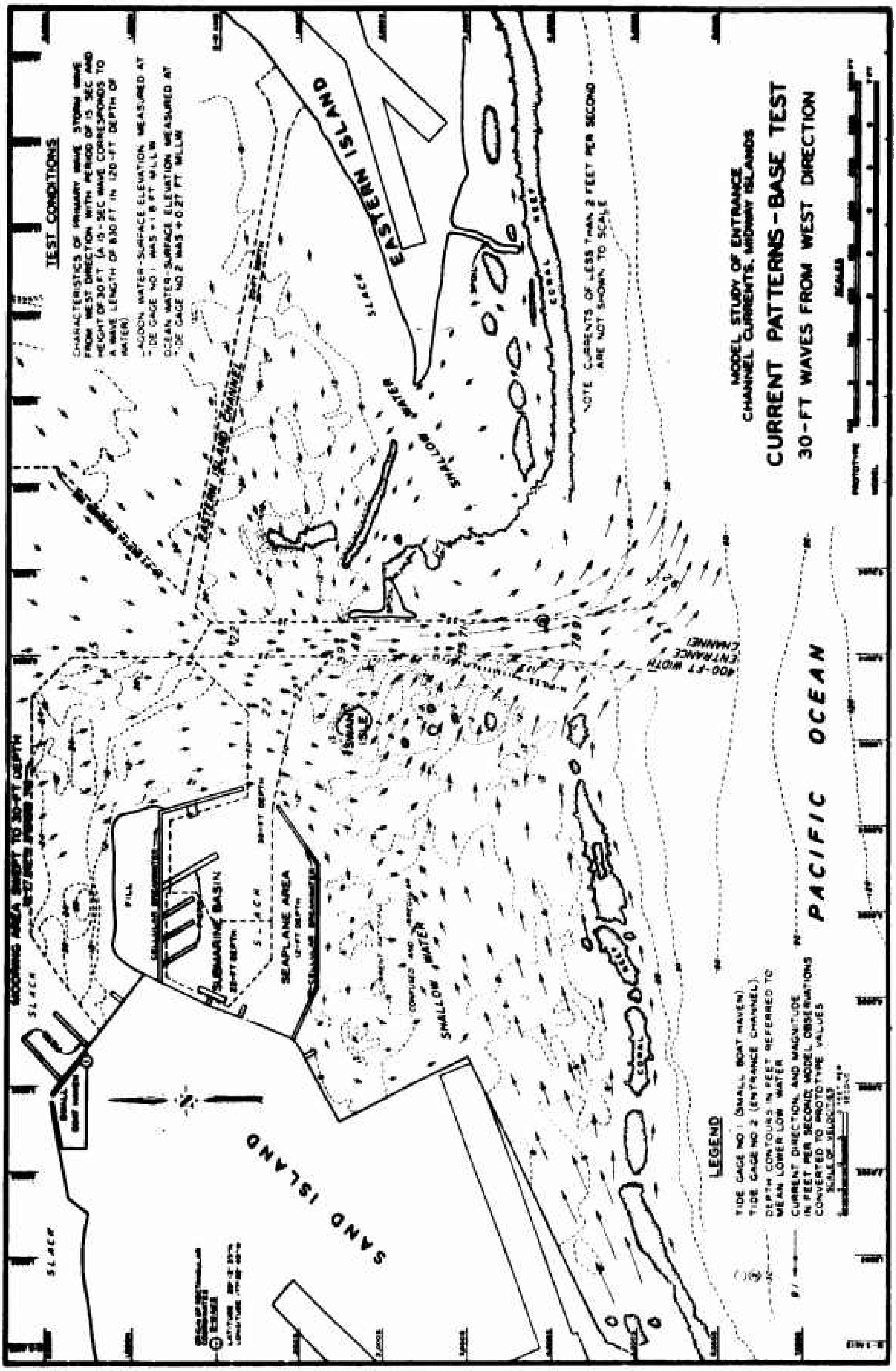

MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
SUBMARINE BASIN
30-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SHALLOW WATER
SMALL ISLE
EASTERN ISLAND CHANNEL
20-FT DEPTH
EASTERN ISLAND
SHALLOW WATER
SPOIL
CORAL REEF
CORAL
REEF
400-FT WIDTH ENTRANCE CHANNEL
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 10 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS + 0.55 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS - BASE TEST
10-FT WAVES FROM WEST DIRECTION
SCALES
PROTOTYPE
MODEL

PLATE 54


TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE: STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 15 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +0.9 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS 0.0 OR MLLW
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS - BASE TEST
15-FT WAVES FROM WEST DIRECTION
EASTERN ISLAND
SAND ISLAND
PACIFIC OCEAN
EASTERN ISLAND CHANNEL
400-FT WIDTH ENTRANCE CHANNEL
SHALLOW WATER
SLACK
CORAL REEF
SPOIL
SAND ISLE
SUBMARINE BASIN
SEAPLANE AREA
CELLULAR BREAKWATER
FILL
SMALL BOAT HAVEN
MOORING AREA SWEPT TO 30-FT DEPTH
NOTE: CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES


MOORING AREA SWEPT TO 30-FT DEPTH
SLACK
SMALL BOAT HAVEN
FILL
CELLULAR BREAKWATER
PIERS
SUBMARINE BASIN
22-FT DEPTH
SLACK
30-FT DEPTH
SEAPLANE AREA
12-FT DEPTH
CELLULAR BREAKWATER
SAND ISLAND
SWAN ISLE
CONFUSED AND IRREGULAR CURRENT PATTERNS
SHALLOW WATER
EASTERN ISLAND CHANNEL
EASTERN ISLAND
SLACK
SPOIL
CORAL REEF
400-FT WIDTH ENTRANCE CHANNEL
PACIFIC OCEAN
TEST CONDITIONS
CHARACTERISTICS OF PRIMARY WAVE STORM WAVE FROM WEST DIRECTION WITH PERIOD OF 15 SEC AND HEIGHT OF 30 FT (A 15-SEC WAVE CORRESPONDS TO A WAVE LENGTH OF 830 FT IN 120-FT DEPTH OF WATER)
LAGOON WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 1 WAS +1.8 FT MLLW
OCEAN WATER-SURFACE ELEVATION MEASURED AT TIDE GAGE NO 2 WAS +0.27 FT MLLW
NOTE CURRENTS OF LESS THAN 2 FEET PER SECOND ARE NOT SHOWN TO SCALE
LEGEND
TIDE GAGE NO 1 (SMALL BOAT HAVEN)
TIDE GAGE NO 2 (ENTRANCE CHANNEL)
DEPTH CONTOURS IN FEET REFERRED TO MEAN LOWER LOW WATER
CURRENT DIRECTION AND MAGNITUDE IN FEET PER SECOND; MODEL OBSERVATIONS CONVERTED TO PROTOTYPE VALUES
SCALE OF VELOCITIES
MODEL STUDY OF ENTRANCE CHANNEL CURRENTS, MIDWAY ISLANDS
CURRENT PATTERNS - BASE TEST
30-FT WAVES FROM WEST DIRECTION
SCALES
PROTOTYPE
MODEL